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NATIONAL SHORELINE STUDY. HAWAII REGIONAL
INVENTORY

Corps of Engineers
Honolulu, Hawaii

August 1971

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Hawaii Regional Inventory

OF THE

National Shoreline Study

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A

The National Shoreline Study

How will the shore be used ?



SHORE MANAGEMENT GUIDELINES

What is its condition ?



REGIONAL INVENTORY REPORTS

What can be done ?

to preserve or enhance the shore,
by using—

- Engineering techniques



SHORE PROTECTION GUIDELINES

REGIONAL INVENTORY REPORTS

- Management techniques



SHORE MANAGEMENT GUIDELINES

In 1968, the 90th Congress authorized this National appraisal of shore erosion and shore protection needs. This National Shoreline Study and the existing Federal shore protection programs recognize beach and shore erosion as problems for all levels of government and all citizens. To satisfy the purposes of the authorizing legislation, a family of 12 related reports has been published. All are available to concerned individuals and organizations in and out of government.

Regional Inventory Reports (one for each of the 9 major drainage areas) assess the nature and extent of erosion; develop conceptual plans for needed shore protection; develop general order-of-magnitude estimates of cost for the selected shore protection; and identify shore owners.

Shore Protection Guidelines describe typical erosion control measures and present examples of shore protection facilities, and present criteria for planning shore protection programs.

Shore Management Guidelines provide information to assist decision makers to develop and implement shore management programs.

Report on the National Shoreline Study, addressed to the Congress, summarizes the findings of the study and recommends priorities among serious problem areas for action to stop erosion.

**Details of illustrations in
this document may be better
studied on microfiche**

STATE OF HAWAII

Regional Inventory Report



**Details of illustrations in
this document may be better
studied on microfiche**

Prepared by
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INTRODUCTION

The shoreline is one of Hawaii's most valuable assets. As an island state, Hawaii is heavily dependent on the deepwater harbors along its shoreline for exportation of its agricultural and manufactured products to overseas markets, and for importation of raw materials and other commodities for local consumption. In addition, the shoreline is the State's most valuable recreational resource. Residents and visitors alike gain much pleasure from relaxing on the sandy beaches, fishing and snorkeling in the nearshore waters, and surfing on the rolling waves.

Development of the shoreline in the past shaped major elements of the State's economy. However, current shoreline development resulting from rapid urbanization, an expanding tourist industry, and a growing population with increased leisure time and income, is reaching unanticipated proportions. Although developments along the shoreline have generally been accomplished to meet demands for recreational beach facilities, they must be judiciously planned and developed to assure that shoreline resources would not be irretrievably lost to future generations.

The anticipated growth of the State's population, economy, and water-oriented recreational activities, and the decrease in open land areas are expected to result in increased and often conflicting demands for shoreline resources. However, these precious resources are finite and must therefore be judiciously utilized if they are to remain for the benefit and enjoyment of present and future generations. Only with knowledge of what the shoreline is, has been, and could become, can sound planning be accomplished to ensure against costly irreparable mistakes, and to reap optimum benefits from the limited shoreline resources through rational choices between competing uses and effective solutions to shoreline problems. This report which summarizes the results of the regional shoreline inventory for the State of Hawaii provides some of the needed information by describing the present condition of the State's shoreline, by defining the scope and magnitude of shoreline problems and by identifying areas where more research and knowledge of our coastal environment are required in order to better assess the short- and long-term consequences of natural and man-caused changes to the shoreline. The regional inventory was accomplished under the authority of Section 106 of Public Law 90-483 (1968 River and Harbor Act). This legislation, which is quoted below, authorizes conduct of the National Shoreline Study and was

passed by the Congress in recognition of the critical problems facing the Nation's shoreline and the need for coordinated effort and a National comprehensive plan to assist state and local governments in solving these problems.

SEC. 106. (a) The Chief of Engineers, Department of the Army, under the direction of the Secretary of the Army, shall make an appraisal investigation and study, including a review of any previous relevant studies and reports, of the Atlantic, Gulf, and Pacific coasts of the United States, the coasts of Puerto Rico and the Virgin Islands, and the shorelines of the Great Lakes, including estuaries and bays thereof, for the purpose of (1) determining areas along such coasts and shorelines where significant erosion occurs; (2) identifying those areas where erosion presents a serious problem because the rate of erosion, considered in conjunction with economic, industrial, recreational, agricultural, navigational, demographic, ecological, and other relevant factors, indicates that action to halt such erosion may be justified; (3) describing generally the most suitable type of remedial action for those areas that have a serious erosion problem; (4) providing preliminary cost estimates for such remedial action; (5) recommending priorities among the serious problem areas for action to stop erosion; (6) providing State and local authorities with information and recommendations to assist the creation and implementation of State and local coast and shoreline erosion programs; (7) developing recommended guidelines for land use regulation in coastal areas taking into consideration all relevant factors; and (8) identifying coastal areas where title uncertainty exists. The Secretary of the Army shall submit to the Congress as soon as practicable, but not later than three years after the date of enactment of this Act, the results of such appraisal investigation and study, together with his recommendations. The views of concerned local, State, and Federal authorities and interests will be taken into account in making such appraisal investigation and study.

The Chief of Engineers report summarizing the findings of the National Shoreline Study, including those presented in this report, was submitted to the Congress in August 1971.

GENERAL PROCEDURE

This report presents the results of an inventory of the shoreline of six of the eight principal islands of the State of Hawaii. The islands of Kahoolawe and Niihau are excluded because their shorelines are not legally accessible to the general public. Emphasis is placed on shorelines within developed areas; shorelines remote from population centers and inaccessible shorelines are not discussed in detail. Emphasis is also placed on the identification of problem areas rather than on problem solution. Therefore, remedial actions suggested in this report are limited to conceptual plans which are intended to provide general guidelines on suitable protection measures for Hawaiian shores.

In preparing this report, maximum use was made of available information from previous studies and reports prepared by the State of Hawaii, the Corps of Engineers, and other governmental and private agencies. In particular, information from "Hawaii's Shoreline" (State of Hawaii Department of Planning and Economic Development, 1965) and "Hawaiian Beach Systems" (Hawaii Institute of Geophysics Report HIG 64-2, 1964) were extensively used. The information from these reports served as the base from which tabulations were made of shoreline parameters required for the Chief of Engineer's report to the Congress. Although the inventory relied heavily on available data from previous studies, it differs from these studies in that it not only describes the physical characteristics of the shoreline, but also provides information on problem areas, particularly beach erosion. Shoreline mileages discussed in the report are based on maps prepared for the "Hawaii's Shoreline" report.

In this report, critical erosion areas are defined as those reaches where erosion presents a serious problem because the rate of erosion, considered in conjunction with economic, industrial, recreational, agricultural, navigational, demographic, ecological, and other relevant factors, indicates that action to halt such erosion may be justified. These areas include recognized problem areas for which requests for remedial action have been received by the Corps of Engineers from State and county government agencies; reaches where concern has been expressed by interested citizens and civic organizations; and reaches where analysis of existing and past shoreline conditions indicate existence of a serious problem in view of current and future use of the area. For each of the six islands, the report lists the areas which are considered to be critically eroding based

on the above criteria. However, only those areas which have been investigated or for which immediate action is considered necessary are discussed in detail in the text.

Non-critical erosion sections are defined as those reaches where erosion is considered to be more conducive to solution by effective shoreline management methods than by physical improvements. Included in this category are areas where erosion is expected to continue such that within 15 to 50 years, the area would be similar to those considered critical in this report. Non-critical erosion areas are not considered to be less significant than critical erosion areas. On the contrary, these areas are probably more important for planning purposes because the future condition of these areas is dependent on expeditious implementation of effective coastal zone management procedures. In recognition of this problem, the Chief of Engineers has published a general report, "Guidelines on Shore Management", which includes reference material on multiple uses of the shore, principles of comprehensive planning and zoning, and other non-structural alternatives to shore erosion problems. Another report, "Shore Protection Guidelines", describes typical methods of shore erosion control, both structural and non-structural, discusses the merits and shortcomings of various shore protection facilities with special reference to their impact on the environment, and presents criteria for designing and using protective measures. These reports are intended to assist State and local authorities and interested parties plan and implement effective shore protection programs.

GENERAL DESCRIPTION OF THE STATE

GEOGRAPHY

The Hawaiian Islands extend some 1,700 miles over the North Pacific Ocean and are part of a volcanic mountain range, most of which is submerged. At the highest part of the range a number of large peaks protrude above sea level, and constitute the major islands of the State of Hawaii, which is the 50th state admitted to the Union, the 47th in size, and 40th in population.

The eight principal islands of the State, from north to south, are Niihau, Kauai, Oahu, Molokai, Lanai, Kahoolawe, Maui, and Hawaii (plate 1). The islands form a 400-mile-long arc at the south-eastern end of the archipelago, and comprise more than 99 percent of the State's land area. These islands were formed by successive flows of basaltic lavas which erupted first from vents in the ocean floor and later from craters and fissures as the lava domes rose above sea level. Of the eight islands, Kahoolawe is uninhabited, and under military control; Niihau is privately owned and little developed. The other six islands therefore constitute the heartland of the State.

The coastline of the state varies greatly in physical characteristics from island to island, and from one district to another on the same island. The volcanic origin and mountainous nature of the islands, however, result in a predominantly bold and rugged coastline with few naturally protected bays or inlets. Towering cliffs rise steeply from the sea to heights of 1,000 feet or more along the northwest coast of Kauai and much of the north coast of Molokai. Lower but similarly precipitous cliffs prevail along the Hamakua coast of Hawaii and in other areas of Hawaii, Maui, and Lanai. In contrast to the rugged coastline, lowlying coasts with sweeping beaches are extensively developed in some areas, particularly on Maui, Oahu, and Kauai.

Another type of coastline is found extensively along the east and north sides of Oahu, the south coast of Molokai, and the north coast of Lanai. Created by inshore and barrier coral reefs, the shoreline in these areas is usually low and rocky with occasional small pocket beaches or an intermittent low shore interrupted by bold headlands.

SHORE OWNERSHIP AND ACCESSIBILITY

In Hawaii, title to all shoreline below the high water mark rests with the state government unless such title has been specifically withheld by the Federal Government or has been transferred to private holdings by legal instrument or by prescriptive right. Table 1 summarizes the ownership of land

above the mean high water mark in 1962. Shoreline ownership has not changed significantly since that time, therefore the data in table 1 are considered to generally reflect current conditions. The relatively stable situation surrounding shoreline land ownership is attributed to the tremendous demand for the islands' limited beach frontages, particularly sandy reaches, which has in effect discouraged sale of these valuable lands.

Table 1
Shoreline Land Ownership
State of Hawaii¹

Owner	Total Shoreline		Sandy Shoreline	
	Miles	% of Total	Miles	% of Total
Federal	106.7	11.4	13.5	7.3
Public (non-Federal)	267.0	28.5	50.0	27.0
Private	560.7	60.1	121.4	65.7
Total	934.4	100.0	181.9	100.0

¹Small offshore islands excluded, except Sand Island and Ford Island.

Source: "Hawaii's Shoreline" prepared by the State of Hawaii Department of Planning and Economic Development in 1965.

Although most of the shoreline below the high water mark are public lands open to all, access to these areas is generally restricted because of physical or legal inaccessibility through abutting properties. As shown in table 1, as much as 60% of the lands abutting the shoreline is privately owned, and only about 28% is owned by the State and counties. Unless some form of right-of-way through private lands is available, the shoreline abutting these properties is not accessible to the general public.

In addition to legal inaccessibility, much of the state's shoreline is physically inaccessible or only marginally accessible. About 64% of the shoreline is comprised of igneous lava basalt which rises from the water's edge in clifflike formations such that the abutting shoreline is either physically inaccessible or marginally accessible, depending on the steepness of the cliffs. Many marginally accessible areas are used for water-oriented recreation primarily by residents who enjoy fishing and diving from the cliffs and collecting shells, "opihii" (type of shell fish) and "limu" (edible seaweed) along the rocky faces.

The State and county governments recognize the value of the shoreline to the socio-economic environ-

ment of the islands, and are striving to increase accessibility to the public shores through acquisition of more public easements and rights-of-way. In addition, the State of Hawaii has enacted a provision requiring that public beach rights-of-way be reserved when public lands along the coast are disposed of. Also, in June 1970, a State law was passed requiring establishment of shoreline setbacks of not less than 20 and not more than 40 feet inland from the high water mark. The law also prohibits removal of sand, coral, rocks, soil, or other beach compositions for purposes other than reasonable domestic use. In addition, the State law prohibits construction of structures, other than those required for safety and shore protection purposes, within the setback area.

The counties within the State of Hawaii have also enacted shoreline setback laws, some of which are more restrictive than the State law. In the case of a conflict between State and county requirements, the State law stipulates that the more restrictive requirement shall be enforced.

DEVELOPMENT OF COASTAL AREAS

Shoreline uses in 1962 are summarized in table 2 which shows that undeveloped land comprised the largest use of the state's shoreline.

Table 2
Shoreline Land Use
State of Hawaii¹

Land Use	Total Shoreline		Sandy Beach	
	Miles	% of Total	Miles	% of Total
Recreational—Public	93.7	10.1	22.7	12.3
Recreational—Private	4.5	0.5	2.5	1.4
Non-recreational				
Development	203.5	21.8	40.9	22.1
Undeveloped	632.7	67.6	118.8	64.2
Total	934.4	100.0	184.9	100.0

¹Small offshore islands excluded, except Sand Island, Ford Island, and proposed reclamation of reef lands in the Keahi Lagoon and off Ala Moana Park ("Magic Island")

Source: "Hawaii's Shoreline" prepared by the State of Hawaii Department of Planning and Economic Development in 1965.

Since 1962, local governments have placed emphasis on development of the shoreline, particularly sandy reaches, for resort and recreational uses. As a result, it is estimated that about 125 statute miles of shoreline were in resort and recreational use in 1970,

an increase of 22 miles since 1962. Most of the newly developed shoreline reaches were previously conservation or open undeveloped land. The continued increase in population and leisure time, and expansion of the tourist industry place greater emphasis on the need for more recreational and resort facilities. Therefore, recreational beach facilities are expected to be the major competitors for developable shoreline reaches of the state.

COASTAL MATERIALS AND PROCESSES

Analysis of the coastal zone requires an understanding of (1) the definition of its components, (2) the origin and composition of the materials within this zone, (3) the natural processes acting on these materials, and (4) the interrelationship between materials and processes over periods of time. A complete, comprehensive understanding of the materials and complex processes along our coastal zone has yet to be attained. Much has been written on this subject, but much research continues. However, because the materials and processes which have shaped Hawaii's coastline are unique, available information on this subject is briefly discussed in this section to provide a better understanding of the remaining sections of the report.

Definition of the Coastal Zone. The nomenclature used in describing a coastal zone and coastal processes are defined below and illustrated in plate 2.

The *shoreline* is the intersection of the surfaces of the sea with the land. Sea level varies about 2 feet each day in Hawaiian waters as a result of tidal forces, therefore the shoreline shifts along the slope of the land as the sea rises and falls. The shoreline as shown on the maps of this report portrays tide level at mean high water.

The *shore* is the strip of land bordering, and as a rule, shaped by the sea.

The *beach* is a shore of unconsolidated material such as sand, cobbles, and boulders. The beach extends landward from the low water line (shoreline at low water) to the place where there is a marked change in material or physiographic form, or to the line of permanent vegetation (usually the effective limit of storm waves). Unless otherwise specified, the seaward limit of a beach is the mean low water line. A beach includes a foreshore and backshore.

The *foreshore* is that part of the shore lying between the crest of the seaward berm (or upper limit of wave wash at high tide) and the ordinary low water mark. It is that part of the shore which is ordinarily washed by the uprush and backrush of the waves as the tides rise and fall.

The *backshore* is that zone of the shore or beach lying between the foreshore and the coast and acted upon by waves only during severe storms, especially when combined with exceptionally high water.

Mean Lower Low Water (MLLW) is the average height of the lower low waters over a 19-year period. For shorter periods of observations, corrections are applied to eliminate known variations and reduce the results to the equivalent of a mean 19-year value.

The *high water mark* is the effective landward limit of wave wash and is sometimes marked by debris. The high water mark is normally the seaward limit of permanent vegetation. (This term is of particular importance because it marks the boundary between the publicly owned Hawaiian shores and privately owned uplands).

The *inshore zone* extends from the low water line through the zone of breaking waves.

The *nearshore zone* extends seaward from the shoreline well beyond the breaker zone. It defines the area of nearshore currents.

The *offshore zone* for Hawaiian waters is defined as the zone extending seaward from the breaker zone to a water depth of about 600 feet. The 600-foot depth contour ranges from about 1 to 10 miles offshore of the islands.

The *coast* is a strip of land of indefinite width (it may be several miles) that extends from the shoreline inland to the first major change in terrain features.

The *coastal zone* includes the land and sea area bordering the shoreline as depicted on plate 2 and in the foregoing definitions.

Critical erosion is defined as erosion which, when considered in conjunction with economic, industrial, recreational, agricultural, navigational, demographic, ecological, and other relevant factors, indicates that action to halt such erosion may be justified.

Bedrock as used in this report generally refers to the relatively solid foundation underlying the characteristically shallow deposits of beach materials. The foundation can be solid coral reef structure, coral reef rubble, beachrock, solid basalt, or basalt rubble. This term is also used to describe solid rock outcroppings.

Beachrock is a stratified calcareous sandstone or conglomerate common along many Hawaiian beaches. Its formation appears to be limited to the beach zone. It can form rapidly as evidenced by the fact that fence wire and coke bottles are found cemented in the rock. Older beachrock which formed at different sea levels of the geologic past are found at elevations higher and lower than present sea level.

The *reef* is a chain or range of rock or coral,

elevated above the surrounding bottom of the sea, generally submerged and dangerous to surface navigation.

The *reef, fringing* is a reef attached to an insular or continental shore.

The *reef, barrier* is a reef which roughly parallels land but is some distance offshore, with deeper water intervening.

The term *Littoral* means of or pertaining to a shore, especially of the sea.

Littoral drift is the material moved in the littoral zone under the influence of waves and currents.

Littoral transport is the movement of material along the shore in the littoral zone by waves and currents.

Tsunami is a long-period wave caused by an underwater seismic disturbance such as volcanic eruption or earthquake. Commonly misnamed "tidal wave".

Composition and Origin of Coastal Material. In general, coastal material can be classified into one of three categories—volcanic, biological, and detrital. Most of the coastal zone is actually comprised of combinations of these materials which are found in various shapes, sizes, and states of weathering and erosion. Although quartz sand is the most dominant worldwide beach constituent, it is absent from Hawaiian beaches primarily because it is not present in lava-basalt and is not formed in the weathering of basalt.

Sea cliffs, rock and other material of volcanic origin comprise about two-thirds of Hawaii's coastline. Their prevalence is attributed to the fact that each of the Hawaiian Islands began as one or more volcanoes that were gradually built up from the sea floor by successive, intermittent extrusions of basaltic lava. The volcanic formation of the islands generally occurred from the northwest down the island chain to the southeast, such that Kauai is the oldest and Hawaii, the youngest, island of the chain. The successive development of the Islands and the recent volcanic activity greatly influenced the characteristics of the Islands' coastlines. Of particular significance is the fact that volcanic activity generally inhibits development of sand beaches in several ways: first, a shoreline may be traversed by a lava flow which may cover an existing sand beach; second, the flow may destroy marine organisms which often produce calcareous sediment; third, recent lava flows on land are highly permeable such that rain infiltrates into the lava rather than flow overland thereby eroding and transporting detrital sediments to the coast where they may nourish a beach; and finally, a section of recent flows crossing the shoreline must undergo extensive marine erosion before a sea cliff or a broad platform is formed whereby waves cross-

ing the relatively flat area will lose enough energy to permit a beach to form and grow.

Although volcanic activity usually inhibits beach development, it sometimes creates beautiful, rare black sand beaches such as those on the southeast coast of the island of Hawaii which has the only two active volcanoes in the state. These beaches are formed by the successive explosion and chilling which occurs when molten lava enters the ocean.

Coastal material of biological origin primarily consists of calcareous sand and coral reefs. The light-colored grains of calcareous sand found around the islands are fragments of skeletal parts of invertebrate animals and algae that lived and died in the sea. Similarly, coral reefs are wave-resistant marine structures which are built in Hawaii and other warm environments by shallow-water organisms. The reefs usually consist of a skeleton or framework of corals and coralline algae. They are another important factor in the coastal processes of the Hawaiian Islands in that they not only contribute calcareous material to form and nourish beaches, but also protect these beaches from damaging wave action. In general, the better sand beaches of the state lie behind well developed reef formations. As such, the older islands, Kauai and Oahu, which have more developed reef systems, have more calcareous beaches than does the island of Hawaii, the youngest island, which has comparatively fewer reefs.

Coral reefs are able to exist in the wave zone because of their massive structure and their ability to repair storm damage by new growth. Reefs which are connected to the shore are called fringing reefs and are the most prevalent type in Hawaii. The characteristics of these reefs vary with wave exposure and, in general, are wide and shallow off windward coasts, wide and very shallow along some leeward or otherwise protected coasts, and deeper and more irregular off northern coasts.

The reefs fringing the windward coasts of Kauai and Oahu are shallow with outer edges from 2 to 12 feet below low tide. From Kahuku to Kaneohe Bay on Oahu the reef is about 1,000 feet wide and is crossed by numerous 30-foot-deep channels with sandy bottoms. The windward coasts typically have poorly sorted fine-grained calcareous sediments on narrow beaches. Plate 3 shows the beach and reef configuration at Hauula Beach Park on the windward shore of Oahu.

The shallowest and flattest reefs are found off protected coasts. Commonly they have volcanic grains mixed in the dominantly calcareous poorly-sorted sands and gravels covering them. Their adjacent beaches are the narrowest beaches in the islands. This type of reef is found on the south coast of Oahu from Koko Head to Pearl Harbor and rims the protected water between Molokai, Maui,

and Lanai. Plate 4 shows the beach and reef configuration at Waialae Beach Park on the south shore of Oahu.

The reef surfaces off the northern and some leeward coasts are much more irregular and deeper than those off of windward and protected coasts. The beaches behind the north coast reefs of Oahu are among the finest on the island. Plate 5 shows the beach and reef configuration at Sunset Beach on the north shore of Oahu.

In addition to material of direct volcanic and biological origin, Hawaii's coastline contains detrital sediments, the result of weathering and erosion of the hinterland. Detrital sediments are usually dark brown in color. They are primarily removed from land by streams and are deposited where the streamflow slackens as it enters the ocean, forming bars, barriers, and deltas, or mixing with other material along the shore. On coasts exposed to moderate wave action, the sediment is worked back and forth in the shallow water and on the beaches, and often forms submerged bars or exposed barriers at the stream mouths. Also, sediment may drift away from their stream-mouth sources as a result of nearshore currents and may form beaches, shallow-water sand patches, and ridges of sand and gravel along nearby reaches.

Shore Processes. The shifting of sand along the coasts of the islands, the movement of sand on and off shores, and any other behavior of sediment in the nearshore or coastal zone of the islands are the result of some force or source of energy. Although all of the sources of the energies reaching the Hawaiian Islands have not been identified, the following sources are thought to be responsible for most of the energy found in the nearshore zone of the islands:

- a. Ocean waves and currents
- b. Atmospheric winds
- c. Tsunamis

Ocean waves and currents are believed to be responsible for almost all of the energy which contributes to deformation of beaches and transportation of sediment along the coasts of the Hawaiian Islands. Depending on the magnitude and direction of the waves and currents reaching the shoreline, sand may move onshore and offshore as it does at Disappearing Sands Beach near Kailua, Hawaii, or back and forth along the shore as at Lumahai Beach, Kauai.

Atmospheric winds, particularly the Northeast Trades and the Kona winds, are also important sources of energy along the coasts of the islands. The Northeast Trades generally prevail from April to November and have average velocities of about 10 to 20 miles per hour from the northeast or east. These winds remove large quantities of sand from the nearshore zone by blowing them inland to form dunes. Kona winds which prevail during November through

March frequently have velocities in excess of 25 miles per hour. However, they are less persistent than the Northeast Trades and are therefore less effective in the movement of coastal sand.

Tsunamis are trains of long-period waves which are impulsively generated in the ocean. Although occurring infrequently, they are a source of very high energy which, upon reaching the coasts of the islands, are usually extremely destructive to the shoreline and to developments along the coast.

Relationship Between Coastal Materials and Processes. Beaches are not static, but are continually changing their composition, structure, and volume seasonally, yearly, or over longer periods of time. Beach changes are not isolated phenomena, but a result of the complex interrelationships between coastal materials and processes over periods of time. Certain relationships between the beach and its surroundings bring about a net increase in the volume of the beach, or beach accretion. Other relationships result in a net loss of sand from the beach, or beach erosion. Also, a combination of accretion and erosion may occur such that a beach is in a continual state of flux, accreting at some times, eroding at other times. These fluctuations are most pronounced between

seasons of the year, reflecting the seasonal variations in the amount and types of wave energy that reach the beaches. Therefore, this phenomenon is often referred to as seasonal accretion and erosion.

Long-term and often relatively permanent changes to the shoreline have both natural and man-made causes. A principal natural cause is the gradual change in the type and magnitude of energy factors reaching the shoreline. The changes in energy factors could cause shifting of sand either along the coast, or onshore and offshore, and the transportation of sand to deep water where it would normally be lost to the nearshore beach system. Other natural causes include winds and storms which often remove sand from the nearshore system and deposit it inland of the normal shoreline area.

Shoreline changes caused by man include the removal of more sand from a particular beach than can be replenished by natural processes, interference with the source of sand for a beach by dredging through reefs, and construction of structures along the shoreline. In addition, pollution of nearshore waters can also ultimately affect natural sources of sand in that it would kill any reef-dwelling animals, the producers of calcareous sand, in the area.

State of Hawaii

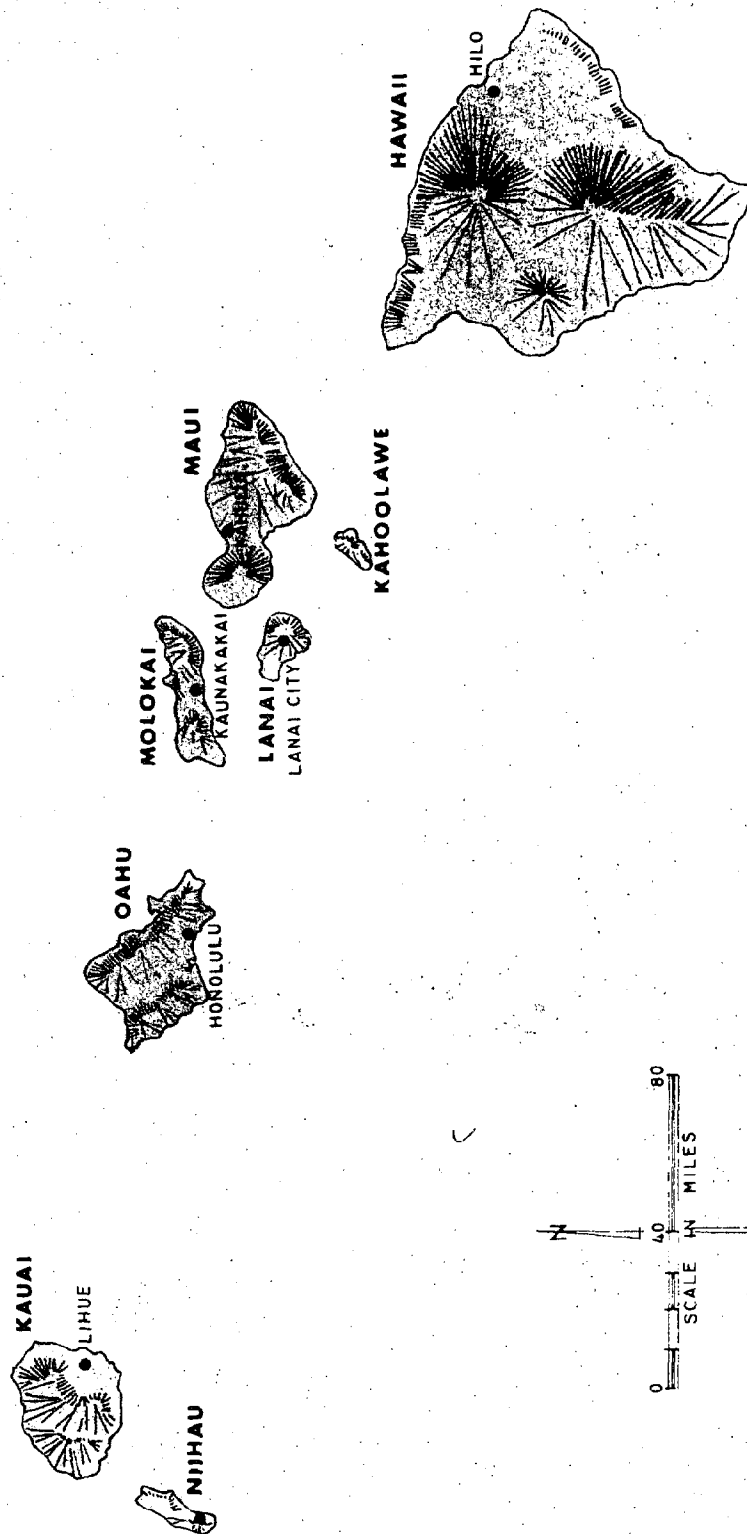


PLATE 1

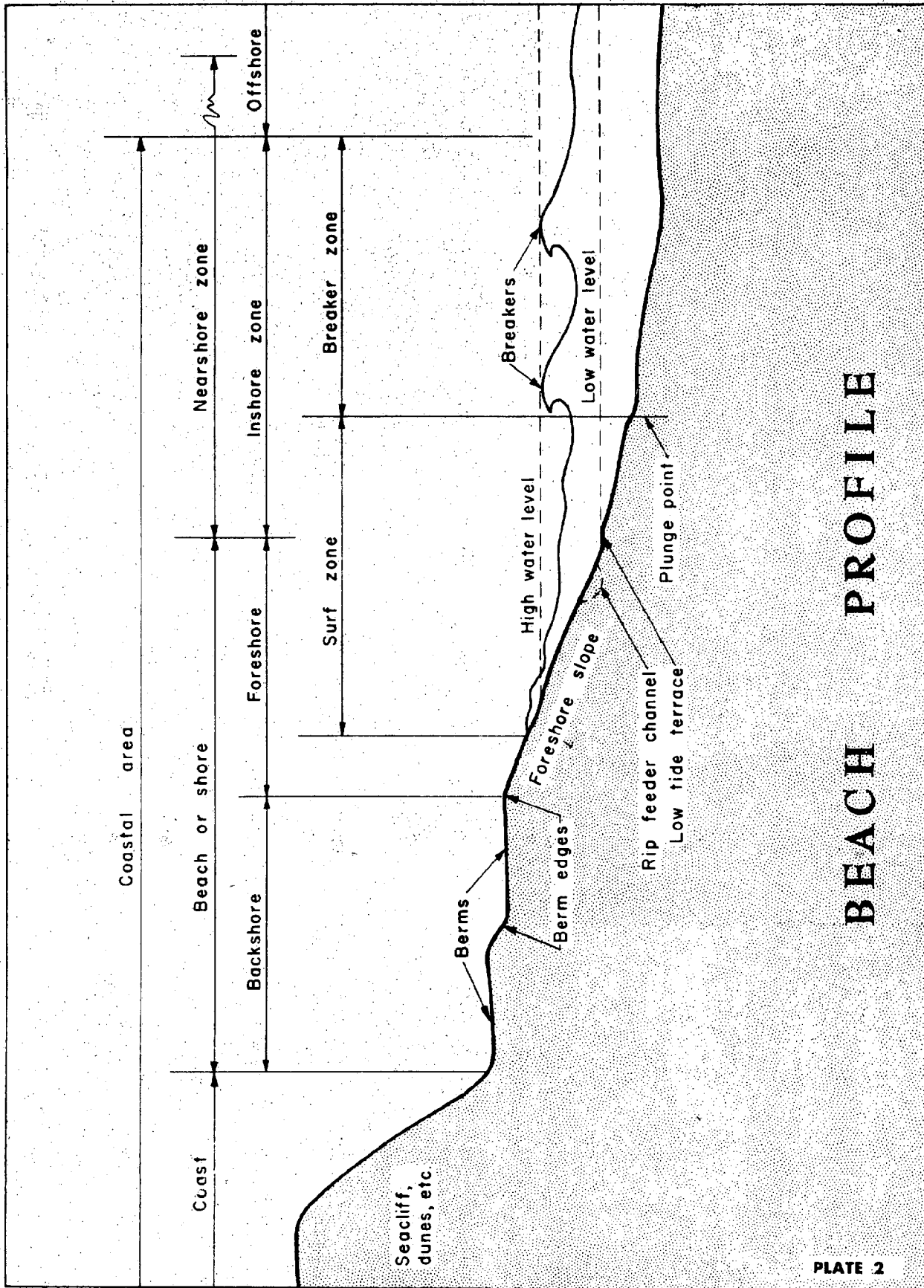


PLATE 2

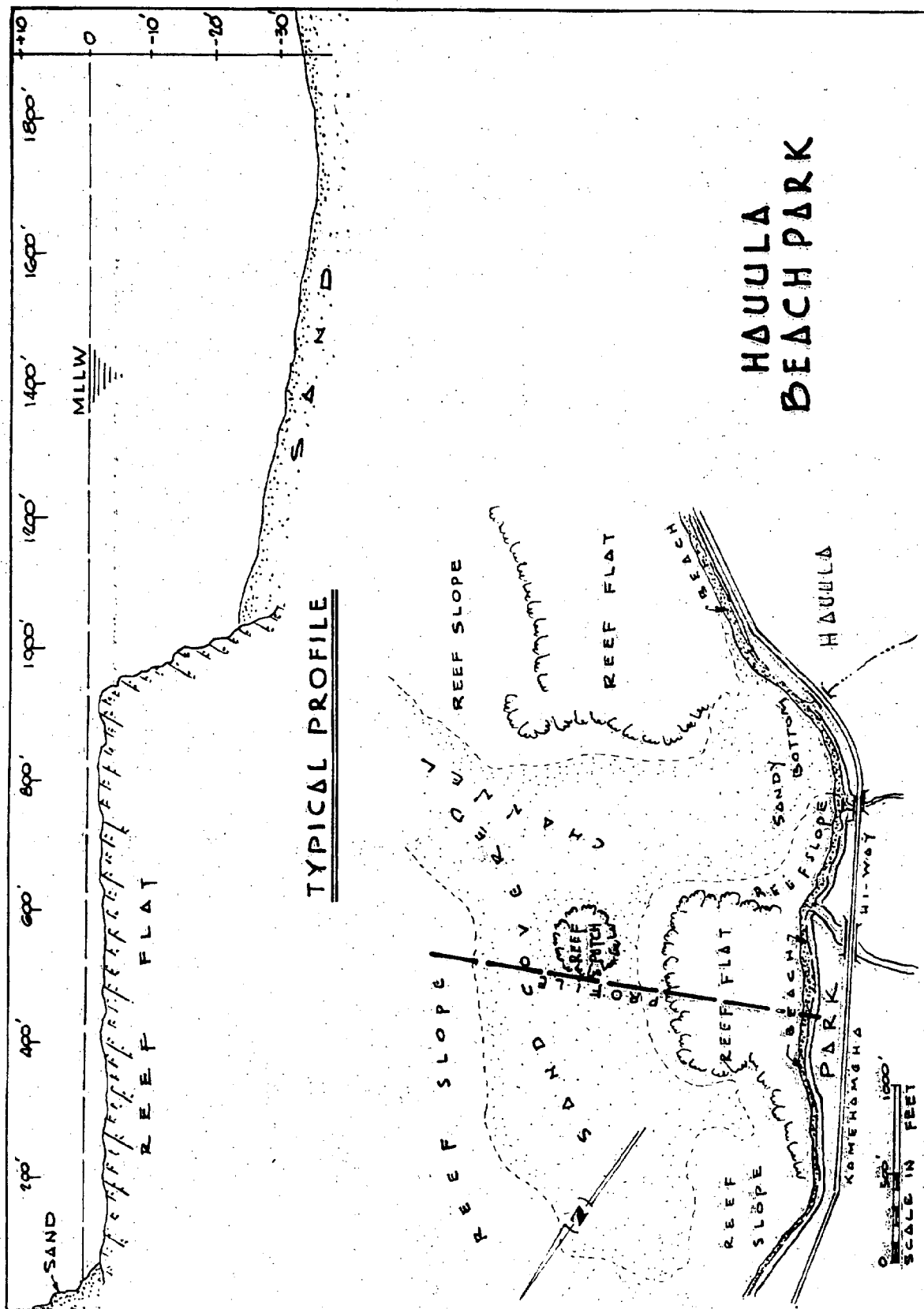
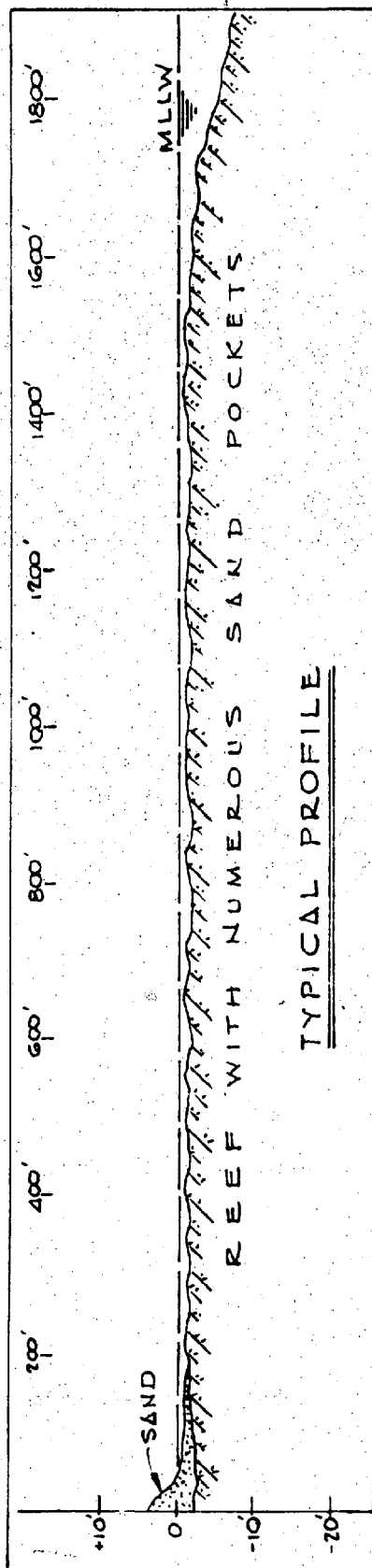
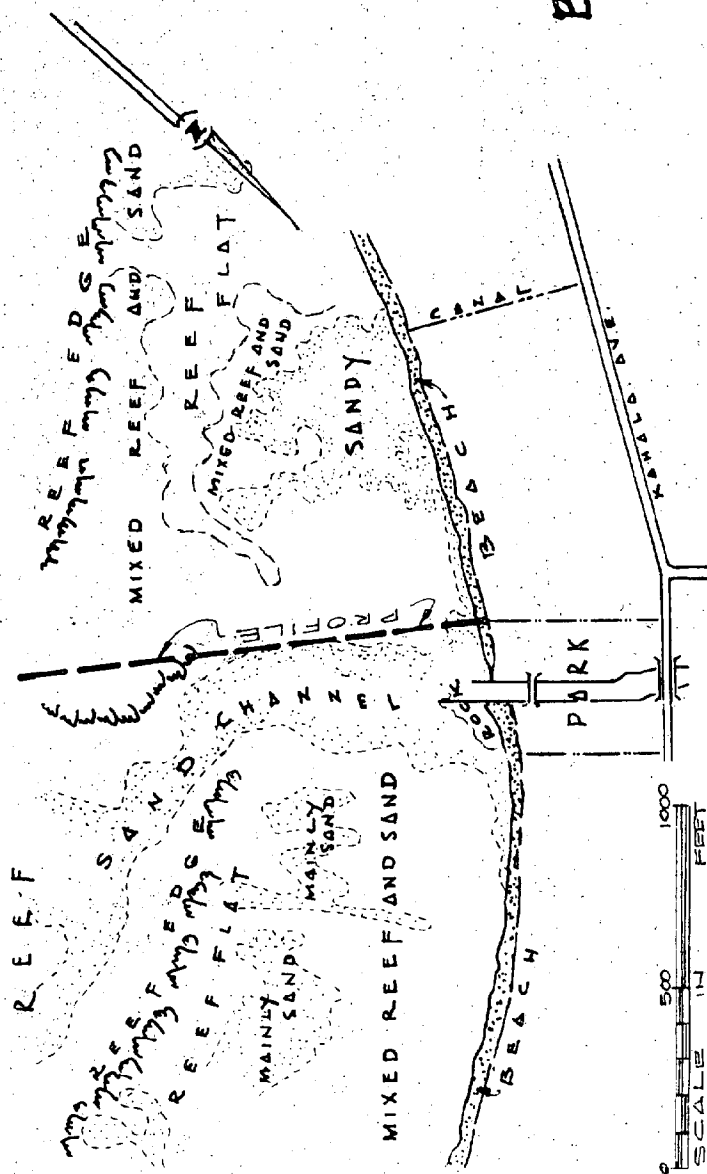


PLATE 3



TYPICAL PROFILE



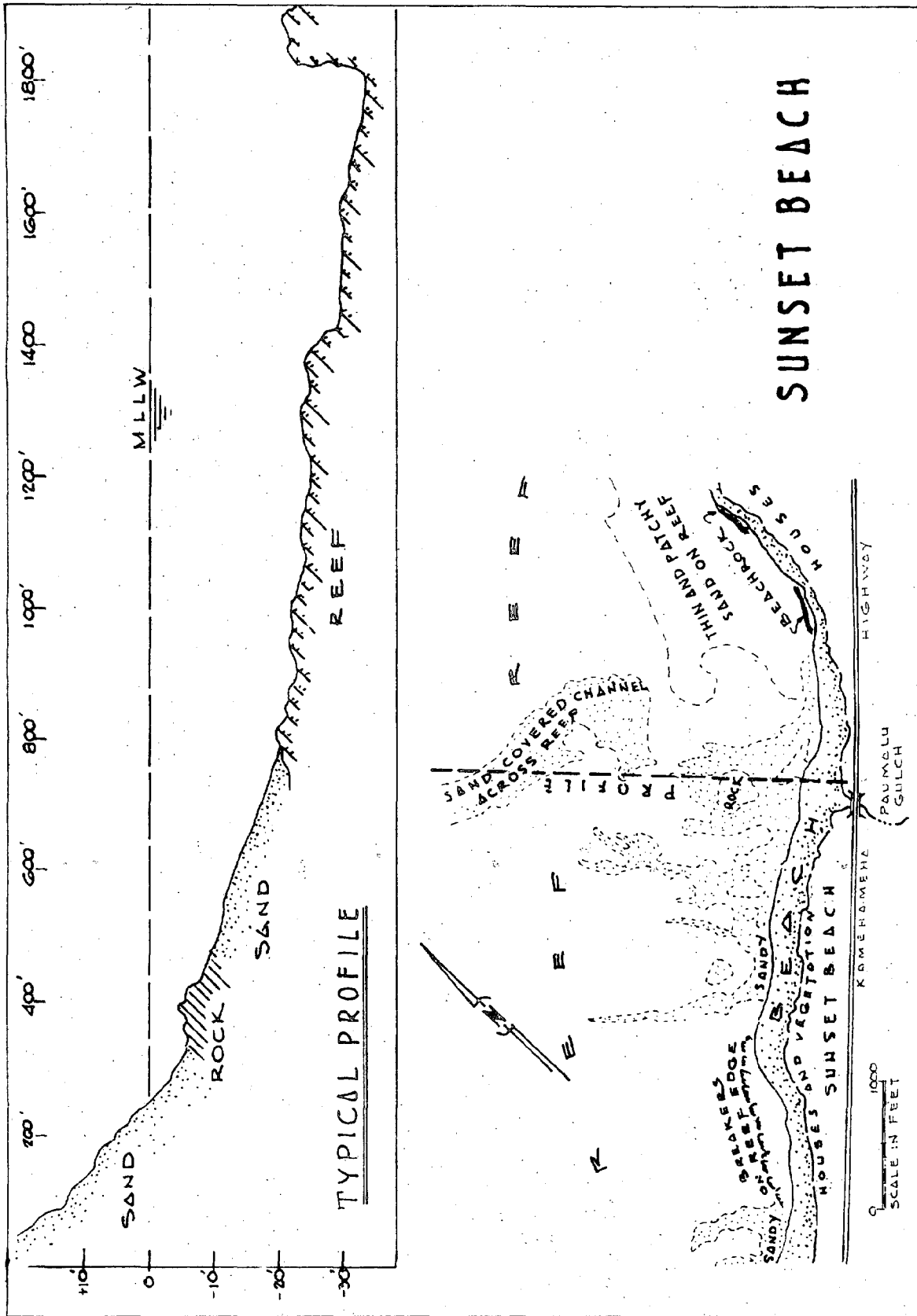


PLATE 5

ISLAND OF KAUAI

GENERAL

The island of Kauai is roughly circular in shape, and has a mean diameter of 26 miles and an area of 555 square miles. It is essentially a volcanic dome which has collapsed in places. Mountainous terrain which comprise the central part of the island rise to heights of more than 5,000 feet. The mountain mass is fringed by a long, narrow, gently sloping coastal plain which contains some of the longest stretches of good beaches in the state. The coastal plain is interrupted on the northwest side by a 16-mile reach of precipitous cliffs which rise from the water's edge, and on the southeast by a narrow ridge called the Hoary Head Mountains which rise to elevations of about 2,280 feet above mean sea level. Most of the agricultural, commercial, and residential developments on the island are concentrated along the coastal plain. The rugged central portion of the island will probably remain as timbered or conservation land.

The tidal shoreline of the island is 113.4 miles long. Eleven miles of shoreline are sea cliffs higher than 1,000 feet and are physically inaccessible. An additional 39 miles are marginally or wholly inaccessible, leaving about 63 miles of physically accessible shoreline. The characteristics of the island's shoreline are summarized in table 3 and are shown on plate 6.

Table 3
Shoreline Characteristics
Island of Kauai¹
(1962)

Characteristics	Miles	Percent
Rock	59.4	52.4
Gravel	1.2	1.1
Sand	49.6*	43.7
Mud (Silt and Clay)	0.0	0.0
Artificial structures	3.2	2.8
Total	113.4	100.0

¹Offshore islands excluded.

*Includes 8.4 miles of seasonal sand beaches where the predominant beach material is sand for only a part of the year.

Source: "Hawaii's Shoreline," prepared by the State of Hawaii Department of Planning and Economic Development in 1965.

SHORELINE USE

Use of land abutting the shoreline is shown on plate 7 and summarized in table 4 which shows

that more than half of the island's shoreline was undeveloped at that time. However, the situation is gradually changing primarily because of the emphasis on development of the tourist industry to enhance the economy of the island. As such, open lands are gradually being developed for resort and recreational beach use.

Table 4
Shoreline Land Use
Island of Kauai¹
(1962)

Land Use	Total Shoreline		Sandy Beach	
	Miles	% of Total	Miles	% of Total
Recreational—Public	11.0	9.7	5.1	12.4
Recreational—Private	0.0	0.0	0.0	0.0
Non-Recreational				
Development	22.6	19.9	10.8	26.1
Undeveloped	79.8	70.4	25.3	61.5
Total	113.4	100.0	41.2	100.0

¹Offshore islands excluded.

Source: "Hawaii's Shoreline," prepared by the State of Hawaii Department of Planning and Economic Development in 1965.

SHORELINE OWNERSHIP

Table 5 shows that private landholdings comprised the largest percentage of Kauai's shoreline in 1962, and that public (non-Federal) interests own the second largest percentage of the island's shoreline. The land ownership pattern reflected in table 5 and shown on plate 8 is expected to remain relatively static.

PHYSICAL CHARACTERISTICS AND HISTORY OF SHORELINE

Table 6 describes the physical characteristics, ownership, use, and condition of the principal sandy beaches of Kauai. The following discussion supplements the data in the table by providing general descriptions of the physical characteristics of the shoreline of Kauai, and qualitative assessments of shoreline conditions. For this discussion, the island was divided into six sections.

Southeast Shore (plate 9). This coastal reach extends from Hanalei Bay to Makahuena Point.

Table 5
Shoreline Land Ownership
Island of Kauai¹
(1962)

<u>Owner</u>	<u>Total Shoreline</u>		<u>Sandy Beach</u>	
	<u>Miles</u>	<u>% of Total</u>	<u>Miles</u>	<u>% of Total</u>
Federal	10.2	9.0	3.3	8.1
Public (non-Federal)	45.3	40.0	16.4	39.8
Private	57.9	51.0	21.5	52.1
Total	113.4	100.0	41.2	100.0

¹Offshore islands excluded.

Source: "Hawaii's Shoreline," prepared by the State of Hawaii Department of Planning and Economic Development in 1965.

It is characterized by stretches of low cliffs of igneous lava basalt which are interrupted by short reaches of sandy beaches or by artificial structures.

The shoreline from Hanamaulu Bay to Carter Point south of Nawiliwili Bay is mainly sea cliffs 20 to 40 feet high, except at the two bays. A 1,500-foot-long, 35-foot-wide rivermouth barrier beach fronts a County park at the head of Hanamaulu Bay. This arcuate beach is relatively stable and has a low slope with no prominent berms. The sand is fine-grained and primarily calcareous in composition. Hanamaulu River enters the bay at the south end of the beach. Sediment discharged from the river contaminates the water and discourages swimming at the beach park. The bottom of Hanamaulu Bay consists of fine sand and silt which are among the finest-grained sediments on Kauai.

Like Hanamaulu Bay, the bottom of Nawiliwili Bay consists of fine sand and silt. Completion of a commercial navigation harbor in 1932 altered the natural shoreline of the bay through construction of a breakwater on the south side, and bulkhead, pier facilities, and a revetted fill area which reclaimed about 48 acres of land on the north side of the bay. The shoreline was further altered in 1956 through construction of another revetted fill area for deposition of dredged spoil from the harbor enlargement project. This fill area reclaimed about 22 acres of land.

Prior to construction of the harbor, a barrier beach existed at the mouth of Huleia Stream on the west side of the bay. Harbor construction reduced this beach to a 300-foot-long, 50-foot-wide reach of calcareous sand.

Kalapaki Beach, a 1,700-foot-long, 75-foot-wide arcuate pocket beach at the north end of Nawiliwili Bay, is bound by cliffs on the east and by the revetted fill area for the harbor on the west. The beach,

which fronts a resort hotel, has a very gentle slope and a low berm which is often cusped. The sand is highly calcareous and consists of medium-sized grains.

Congress has authorized the U.S. Army Corps of Engineers to construct a small boat harbor within Nawiliwili Bay between the revetted fill area at the northwest end of the commercial navigation harbor and the mouth of Huleia Stream. The harbor improvement consists of construction of an entrance channel, dike, and mole to provide a useable area of 15 acres and accommodations for 200 boats. No date has been set for construction of this harbor.

The Haupu coast, which extends from Carter Point to about four miles southwest of Kawelikoa, is characterized by high and rugged sea cliffs. The southwest end of this coast is called Kipu Kai and is characterized by three excellent sandy beaches which average about 100 feet in width. The relatively straight northern beach is separated from the middle beach by a rocky ridge with boulders at its seaward end. The crescent-shaped middle beach is backed by active dunes 20 to 30 feet high, and is separated from the southernmost beach by a pair of small rocky ridges. The one-fourth mile long southernmost beach, the longest of the three beaches, is backed by stable dunes 50 to 60 feet high. A narrow but shallow reef fronts part of the northernmost beach, and other irregular reef areas are present along this coast (plate 10); however, the water is generally 60 or more feet deep within a half mile of the Haupu shoreline.

From Kawelikoa Point to Makahuena Point, the shoreline consists of a series of rocky points between which are beaches backed by active dunes (figure 1). These dunes extend about three-fourths of a mile inland.

South Shore (plate 9). The 15.5-mile-long south shore extends from Makahuena Point to Makaweli Landing. Much of the shoreline along this reach consists of outcrops of lava basalt or calcareous sandstone. The several beaches scattered between the rocky shoreline are both short and narrow, and some of them are seasonal, that is, the sand erodes away during the winter months and returns during the summer.

The 4,000-foot-long Poipu Beach at the east end of this reach fronts a rapidly developing resort area. This reach consists of several arcuate beaches between rocky points along the coast. The beaches are between 60 and 70 feet wide and are often moderately steep with no noticeable berms (figure 2). The sand consists of fine calcareous grains with only minor amounts of detritus. A reef fringes the shoreline and provides a calm, relatively sheltered swimming area.

The reach from Poipu Beach to Hanapepe Bay is primarily sea cliffs of outcropping lava basalt, except for the reaches fronting Lawai, Wahiawa, and Hanapepe Bays which are drowned river-valley mouths. A

Table 6
Characteristics of Principal Beaches on Kauai

Name	Stability Classification Length in 1,000 Feet			Length Feet	Width Feet	Type of Beach		Predominant Beach Composition	Shore Ownership Public			Shore Use in Linear Feet			
	Critical Erosion	Non-Critical Erosion	Non-Eroding			Natural	Artificial		Federal	Non-Federal	Private	Public	Recreational	Non- Recreational	Undeveloped
Southeast Shore															
Hanalei Beach Park		2		1,500	35	X		Calcareous		X		1,500			
Nawiliwili Bay (Kalapoko Beach)				1,700	75	X		"			X			1,700	
Kipu Kai Pocket Beaches		3		3,000	100	X		"			X				3,000
South Shore															
Poipu Urban Beaches		2	2	3,700	60	X		"			X				3,700
Poipu Beach Park			1	300	70	X		"		X		300			
Lawai Bay			1	1,300	70	X		"			X			1,300	
Hanalei Beach	3			2,700	30	X		Volcanic		X ¹				1,700	1,000
Southwest Shore															
Mahimahi		1		1,400	70	X		Volcanic			X				1,400
Waimea East		5		5,000	100	X		"			X				5,000
Waimea West	3	4		7,000	100	X		"			X			3,000	4,000
Kekaha	8	9		17,000	150	X		Calcareous		X ²		7,000			10,000
Barking Sands	8	6		11,000	300	X		"	X					14,000	
Pali Hale		20		20,000	300	X		"		X		20,000			
North Shore															
Ke'e Beach		1		500	35	X		"			X				500
Kepuhi		5		4,500	75	X		"			X				4,500
Waimea Bay			1	1,300	150	X		"			X				1,300
Lanikai Beach		4		4,000	200	X		"			X				4,000
West Hanalei		5		5,000	125	X		"			X				5,000
Waialeale Beach Park			2	2,000	125	X		"			X		2,000		
East Hanalei			4	4,000	125	X		"			X				4,000
Anini			1	1,000	30	X		"			X			1,000	
Kalihiwehi		2		1,500	100	X		Volcanic			X				1,500
Kaunapala			3	3,000	75	X		Calcareous			X				3,000
Molokai			2	2,000	175	X		"			X				2,000
Northeast Shore															
Papaia Bay		2		2,000	35	X		"			X				2,000
Anahola Bay		7		6,000	150	X		"		X ³		600		1,000	5,000
Kapaemahu	4			4,000	25	X		"		X				4,000	
Kalihiwehi		1	2	2,500	100	X		"		X				2,500	

¹1,000 Ft. Public, 1,700 Ft. Private.

²7,000 Ft. Public, 10,000 Ft. Private.

³600 Ft. Public, 6,000 Ft. Private.



Fig. 1 Makahuene Point, Kauai (Camera Hawaii Photo)

boat launching ramp at Koloa and a boat harbor at Kukuiula are the only artificial structures within this reach. Sandy beaches exist at the head of Lawai and Wahiawa Bays. A half-mile-long rivermouth barrier beach which existed at the head of Hanapepe Bay has been critically eroded. In 1962, this arcuate sand beach had an average width of 70 feet. Since that time the beach has undergone continual erosion, and is presently completely denuded except for a 30-foot-wide bar which partially blocks the mouth of the Hanapepe River. The sand along this beach is predominantly medium-sized grains of volcanic detritus deposited by the river. The severity of the erosion problem resulted in a request from the State of Hawaii for Federal participation in a beach erosion control project. Plans and specifications for such a project have been completed by the Corps of Engineers, however, construction of the project has not been initiated.

The east side of Hanapepe Bay has been altered by construction of the Port Allen Commercial Navigation Harbor in 1935 and the Port Allen Recreational Small Boat Harbor in 1962. Artificial structures include a 1,200-foot-long rubblemound breakwater, a 600-foot-long pier, a 1,000-foot-long revetted mole, and rubblemound revetments along the existing shoreline.

The shoreline from the west end of Hanapepe Bay to Makaweli Landing is primarily rocky outcrops of lava basalt, with a few short sandy beaches along some of the inlets within this reach.

Southwest Shore (plates 9 and 11). This 18-mile reach which extends from Makaweli Landing to Polihale is distinguished by long stretches of beach and the only extensive coastal plain on the island. The coastal plain is more than two miles wide in the center of this reach, and tapers to the north and south-east. Except for the towns of Waimea and Kekaha and a military airfield, this reach is undeveloped.

Mahinauli Beach is a 1,400-foot-long, 70-foot-wide beach composed of poorly sorted medium grains which contain a high percentage of volcanic detritus. The beach is bound on the south by the Makaweli Jetty and on the north by a point of land composed of rock and sand. It is protected from excessive wave action by a reef approximately 700 feet offshore.

A 7,000-foot-long, 100-foot-wide beach extends west from Waimea River to the Kikiaola Small Boat Harbor. This beach, which fronts the town of Waimea, is predominantly composed of grains of volcanic sand deposited by the Waimea River. The percentage of volcanic components decreases along the western end of this beach. This decrease is attributed to a westward-flowing alongshore current which moves the sand along the beach and dilutes the volcanic component by the addition of calcareous grains from the shallow water offshore. The foreshore slope varies

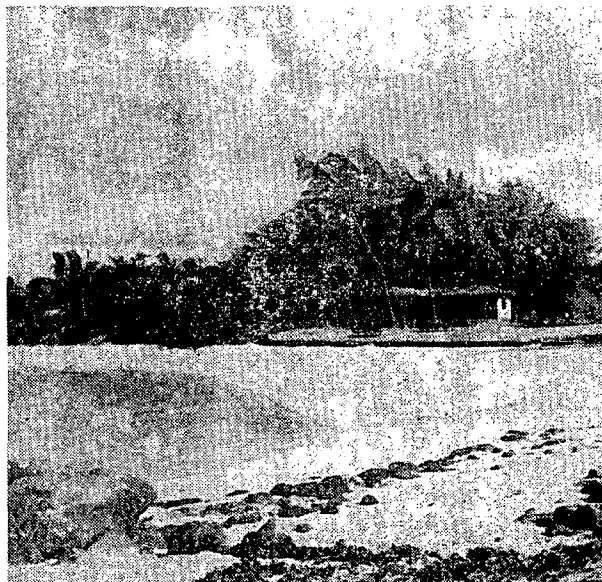


Fig. 2 One of several beaches at Poipu, Kauai

from steep in winter to moderately steep during the summer. The water is usually muddy due to alluvial sediments from the Waimea River.

The shoreline extending about 3,000 feet west of Waimea River has eroded continually since the early 1900's. The erosion became a critical problem when it endangered beachfront properties and threatened the road parallel to the beach to the extent that it was relocated further inland three times between 1940 and 1955. After the last relocation, emergency riprap protection was placed along the eroding bank. The severity of the erosion problem resulted in a request for Federal assistance in a shore protection project. In 1958, Congress authorized the use of Federal funds to pay for one-half the cost of a 1,240-foot-long rubblemound seawall which would be constructed by the State of Hawaii to protect public shores fronting Waimea town. To date, no work on this project has been initiated.

Artificial structures of the Kikiaola Small Boat Harbor have altered the natural shoreline west of Waimea Beach. These structures include a 600-foot-long rubblemound west breakwater, a 1,170-foot-long rubblemound east breakwater, a concrete launching ramp, and a 200-foot-long groin.

Kekaha Beach, which is about 17,000 feet long and averages about 150 feet wide, extends from the small boat harbor to the Naval reservation at Barking Sands. Sand along this reach is about 70 percent calcareous and 30 percent volcanic detritus in composition. Critical erosion has occurred along a 4,700-foot reach fronting the public beach park. In 1936, the shoreline near the western end of the park was 100 feet seaward of the present highway and that near the eastern

end was 200 feet seaward of the highway. Erosion over the years moved the shoreline right up to the highway, and necessitated dumping of rock on several occasions since 1958 to protect the highway revetment. Comparison of a survey made in 1966 with one made in 1936 showed that erosion was most significant at the east end of the park. The comparison also showed that an average width of 110 feet eroded over a 3,200-foot reach. This is equivalent to a total loss of 352,000 cubic yards of sand during the 30-year period, which is an average annual loss of 11,700 cubic yards. The severity of the erosion problem led to a request from the State of Hawaii for Federal participation in a beach erosion control project. However, investigation of the problem disclosed that Federal assistance in the construction of a permanent revetment to protect the highway could not be provided because of the high cost of the proposed revetment compared to the economic savings which would result from reducing erosion along this reach. However, the Corps of Engineers stated in their report that continued dumping of rock by local government agencies on an as-required basis would retard erosion and provide some protection for the beach.

From Kekaha Beach, Barking Sands Beach extends northwest around Kokole Point, a cusped foreland, to the Barking Sands Naval Airstrip. This 14,000-foot-long beach ranges in width from 100 to 200

feet and is backed by extensive sand deposits. The sand is primarily white calcareous fragments with a small percentage of volcanic detritus. North of this sandy beach, a 3.5-mile reach of beachrock backed by a storm beach extends to Nohili Point (figure 3). The beachrock along the south end of this reach is exceptionally massive.

Polihale Beach, a 20,000-foot-long, 300-foot-wide beach, lies north of Nohili Point. The beach along this reach is more than 20 feet in depth, and is backed by 50-foot-high sand dunes. Extensive outcrops of beachrock exist at sea level.

Northwest Shore (plate 11). The Na Pali Coast, a 14.5-mile-long shoreline between Polihale and Kai-liu Point, is characterized by precipitous sea cliffs which are among the highest and most scenic in the state. Except for two state beach parks, this physically inaccessible reach is undeveloped.

The hinterland of this shoreline consists of lava basalt flows and dikes of the Waimea Canyon volcanic series which have been cut into deep valleys by stream erosion. The ends of the interstream ridges have been cut into the spectacular cliffs by marine erosion. Between Polihale and Milolii, the faceted cliff-ends of the ridges are fairly straight and about 1,250 feet high. Beyond Milolii, the cliffs are higher but are more irregular because of broader valleys. At a few places the cliffs rise to about the 3,000-foot elevation within one mile of shore.

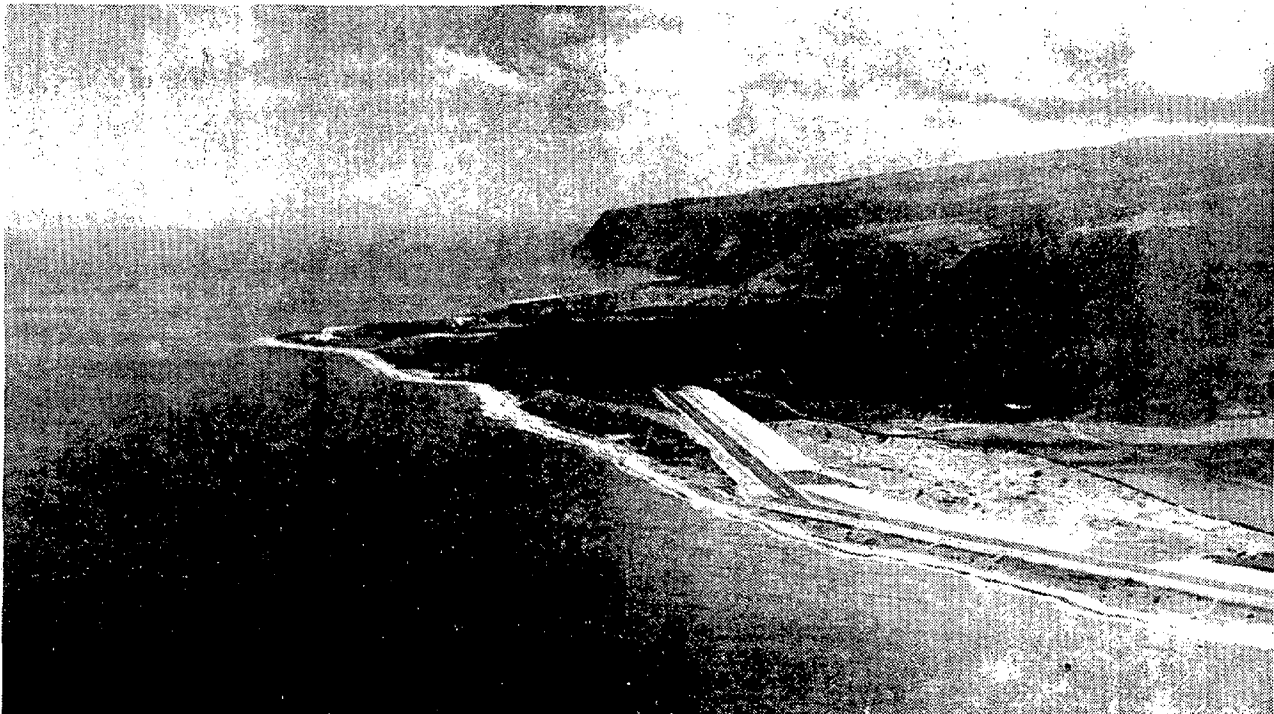


Fig. 3 Barking Sands area, Kauai

The Na Pali shoreline is primarily lava bedrock, but there are boulder beaches and small seasonal sand beaches at the foot of some of the cliffs, at some of the small inlets along this coast, and especially at the mouths of some streams. Small sand beaches at Honopu Valley, at the bay one-third mile east of the valley, and at the south end of the long sand beach at Kalalau are present throughout the year.

North Shore (plate 11). This 18-mile shore extends from Kailiu Point (figure 4) to Moloaa Bay, and is characterized by alternating stretches of sand and bedrock, small bays which are drowned river valleys, and lengthy stretches of shallow fringing reefs off-shore. Most of the beaches along the north shore undergo significant seasonal changes, primarily as a result of erosion by winter northern sea swells.

Beaches along this shore also experience changes resulting from severe flooding of the rivers as well as from changes in river courses. Except for a resort area at Hanalei Bay and a military reservation at Kilauea Point, developments along the north shore consist of scattered rural residential and agricultural areas. Much of this shore is undeveloped.

About two-thirds of the north shore is fringed by shallow reefs. The reef flats west of Kalihiwai are as much as 1,600 feet wide, but are about half this width along the southeast end of this coast. Farther off-shore, a very broad submarine ridge extends north-eastward from Kauai into deep water.

Keel Beach west of Haena Bay is 500 feet long and 35 feet wide. The beach is composed primarily of calcareous fragments with beachrock exposed at sea level in a few locations.

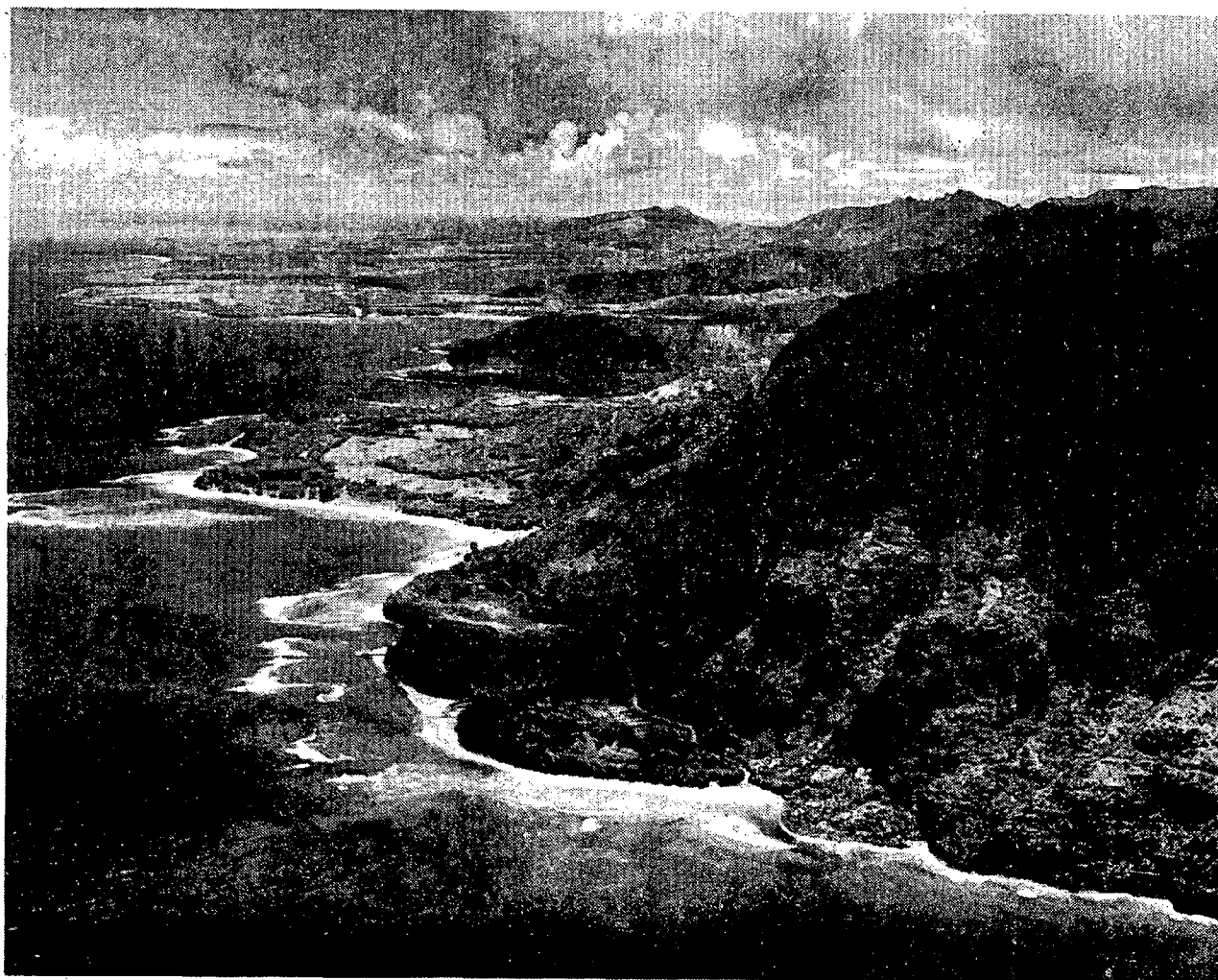


Fig. 4 Kailiu Point and Hanalei Bay area, Kauai (Camera Hawaii Photo)

The 1,300-foot-long arcuate beach at Haena Bay is about 200 feet wide in the center section, but narrows to the west where it terminates at a mound of boulders behind a coral reef. Low vegetated dunes lie back of the beach which is composed primarily of calcareous sand. The foreshore at the beach park in the center of the bayshore is very steep because it receives no protection from the fringing reef that lies off the sides of the bay.

Kepuhi Beach is a 4,500-foot-long beach on the broad point between Haena Point and Wainiha Bay. The beach averages 75 feet in width except for an area along the west end which is about 150 feet wide. The beach sand is highly calcareous in composition. Although a shallow reef flat provides some protection, the beach was seriously eroded in February 1963. However, most of the sand returned to the beach by August of the same year. Although erosion continues at this beach, it is considered to be non-critical at this time.

The 1,300-foot-long barrier beach at Wainiha Bay has an average width of 150 feet. It is about 200 feet wide at the west end where it joins a physically inaccessible reach of low cliffs, and is about 100 feet wide at the east end. The beach has a fairly steep slope and is composed of both volcanic detritus deposited by the Wainiha River and calcareous material from the adjacent sea floor.

Lumaha'i Beach, east of the mouth of Lumaha'i River, is about 4,000 feet long. The width of the beach varies seasonally, but is about 200 feet wide on the average. During the winter, sand usually moves from the west to the east. Surveys made by the University of Hawaii showed that in August 1962 the west end of the beach was 350 feet wide, but in February 1963, it was denuded and waves were eroding the low dunes behind the beach. During this same period, the east end of the beach accreted from 160 to 435 feet. The beach generally has a steep foreshore because of the absence of a protective reef.

Hanalei Bay, the largest bay on Kauai, is a half circle which opens to the north. Detritus deposits at the mouths of the Hanalei, Waioli, and Waipa Rivers which empty into the bay, and calcareous sands from offshore organisms have been reworked by the waves into a 2-mile-long beach. The beach has a gently sloping foreshore, and an average width of 125 feet, although seasonal changes occur. Some erosion has occurred along the west Hanalei Beach which extends from Makahoa Point to Waioli Beach Park near the center of the bay shore. However, the problem is not considered serious at this time. The beach extending from the park to the east end of the bay is relatively stable.

The only artificial structure along the north shore is a 300-foot-long pier about 600 feet south of the mouth of the Hanalei River. Although plans for a small boat

harbor at this site have been prepared by the Corps of Engineers, construction of the project has not been initiated. The proposed small boat harbor would alter the shoreline by construction of a 380-foot-long jetty and dredging of an entrance channel and berthing basin in the peninsula between the bayshore and the river estuary.

The shoreline extending eastward from Hanalei to Kilauea is a sea cliff which ranges in height from 100 to 200 feet. West of Anini Stream, a few small beaches exist in front of the cliff. The beach at Anini Stream and beaches eastward are longer and wider.

Kalihiwai Bay, a drowned river valley, has a 1,500-foot-long, 100-foot-wide rivermouth barrier beach. This seasonally varying beach is generally narrower at the east end where it abuts a boulder beach at the base of a cliff that forms the east side of the bay. The beach has a low slope with at least one berm. Beach sand is medium-to-coarse grained, and is predominantly detrital material deposited by the river.

Kauapea Beach, a 3,000-foot-long, 75-foot-wide sandy beach between Kalihiwai Bay and Kilauea Point is the last long sandy beach along the north shore. This beach is only marginally accessible as it fronts on rugged, undeveloped land. The remaining reach from Kilauea Point to Molokaa Bay consists of about half beach and half sea cliffs which rise 20 to 200 feet high. The cliffs are highest near Kilauea and Molokaa Streams. Most of this reach fronts on undeveloped land and is only marginally accessible.

A slightly arcuate, 2,000-foot-long, 175-foot-wide rivermouth barrier beach exists at Molokaa Bay. The foreshore has a low slope which is broken in places by outcrops of beachrock. Beach sand is predominantly calcareous with only small quantities of sand-sized detritus. Low dunes behind the beach are vegetated with grass and ironwood trees. A long outcropping of beachrock exists in the surf zone, but the bottom seaward of this outcropping is predominantly sand.

Northeast Shore (plate 11). The northern half of this coastal reach extends from Molokaa Bay to Kealia, and is characterized by low sea cliffs fringed by shallow reefs, with a few bays which are drowned river-valley mouths. In cliff height and embayment the shoreline closely resembles the southeast shore. Except for the river valleys, coastal lowlands along this reach are scarce and physical accessibility to the shoreline is marginal. Other than two small beach-front residential areas and a public beach park in the Anahola Bay area, the shoreline along this reach is essentially undeveloped. The southern half of the northeast shore extends from Kealia to Hanamaulu Bay, and is generally low with heavy resort development around Wailua Bay. Rivers along this reach empty into gentle scallops of the coast rather than into deeper bays.

The 6,600-foot-long Anahola Beach has an average



Fig. 5 Anahola Beach, Kauai (Camera Hawaii Photo)

width of 150 feet. This slightly arcuate beach is from 170 to 220 feet wide near the center and narrows to about 100 feet at both ends (figure 5). The beach has a low slope and at least one berm. Beach sand is predominantly calcareous and of medium-grain size. The offshore is essentially sand, and low sand dunes lie behind part of the beach. The beach is subject to seasonal accretion and erosion, and to changes resulting from lateral shifts in the mouth of the perennial Anahola Stream. During the 16-month study of Hawaiian beaches conducted by the University of Hawaii, the position of the stream mouth changed by about 500 feet.

Kēalia Beach is a 2,500-foot-long, and 150-foot-wide beach between a rocky point on the south and a small jetty on the north. Kapāa Stream crosses the south end of this beach which consists of highly calcareous sand. Behind the beach are low dunes,

a cane-hauling road, and the main highway. The remnants of a small sand-mining operation are located at the north end of the beach.

Kapāa Beach extends from about 2,000 feet north of Moikeha Stream to Waieka Stream and fronts a public beach park. The beach averages about 25 feet in width and consists of fine to medium grains of calcareous sand. It is fringed by a coral reef ranging from 400 to 1,500 feet in width. Artificial structures along this reach include jetties at the mouth of the two streams and a 900-foot-long rubblemound revetment at the north end of the park. This revetment was completed by the State of Hawaii in 1964 to protect the shoreline from erosion which had been occurring since 1959. Surveys made in June 1959 and January 1963 showed that an average of 40 feet of beach was lost along a 1,000-foot-long reach. The erosion,

which was confined to this one reach of the beach, was attributed to dredging of the offshore coral reef in 1959. Prior to this time, annual changes at the beach were small, and sand was usually transported shoreward along reef channels, then toward the stream outlets, and out to sea from where the cycle was repeated. However, the dredged area severed the reef channels so that sand became trapped in the dredged area, thereby preventing natural nourishment of the beach. Construction of the revetment has prevented further loss of beachfront property along this 900-foot reach.

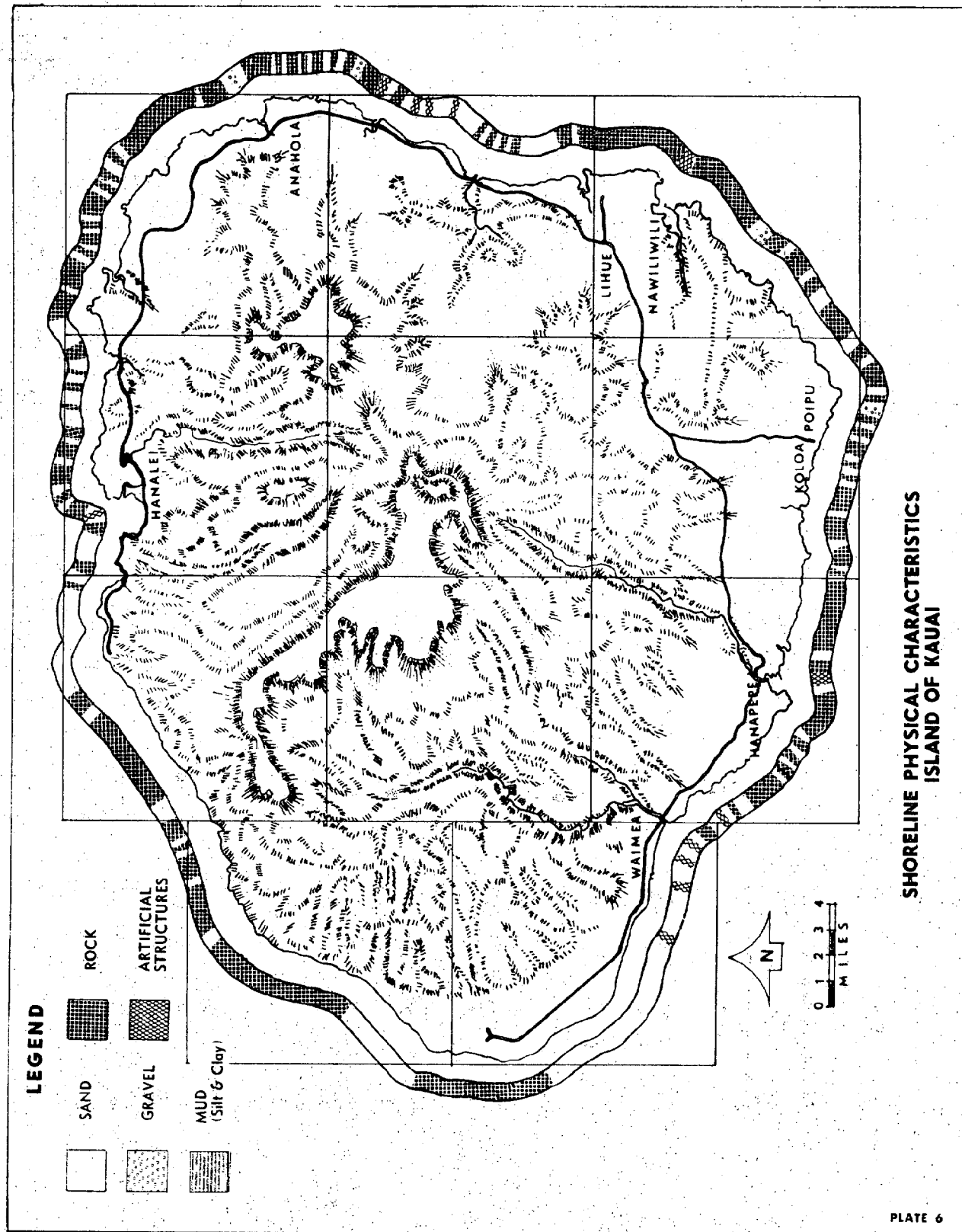
A 2,500-foot-long, 100-foot-wide rivermouth barrier beach exists at Wailua Bay. The north end of this slightly arcuate beach is more stable than the south end which terminates at the mouth of the Wailua River and which is subject to erosion resulting from flooding of the river. In April 1963 the beach along the south end eroded to the vegetated backshore

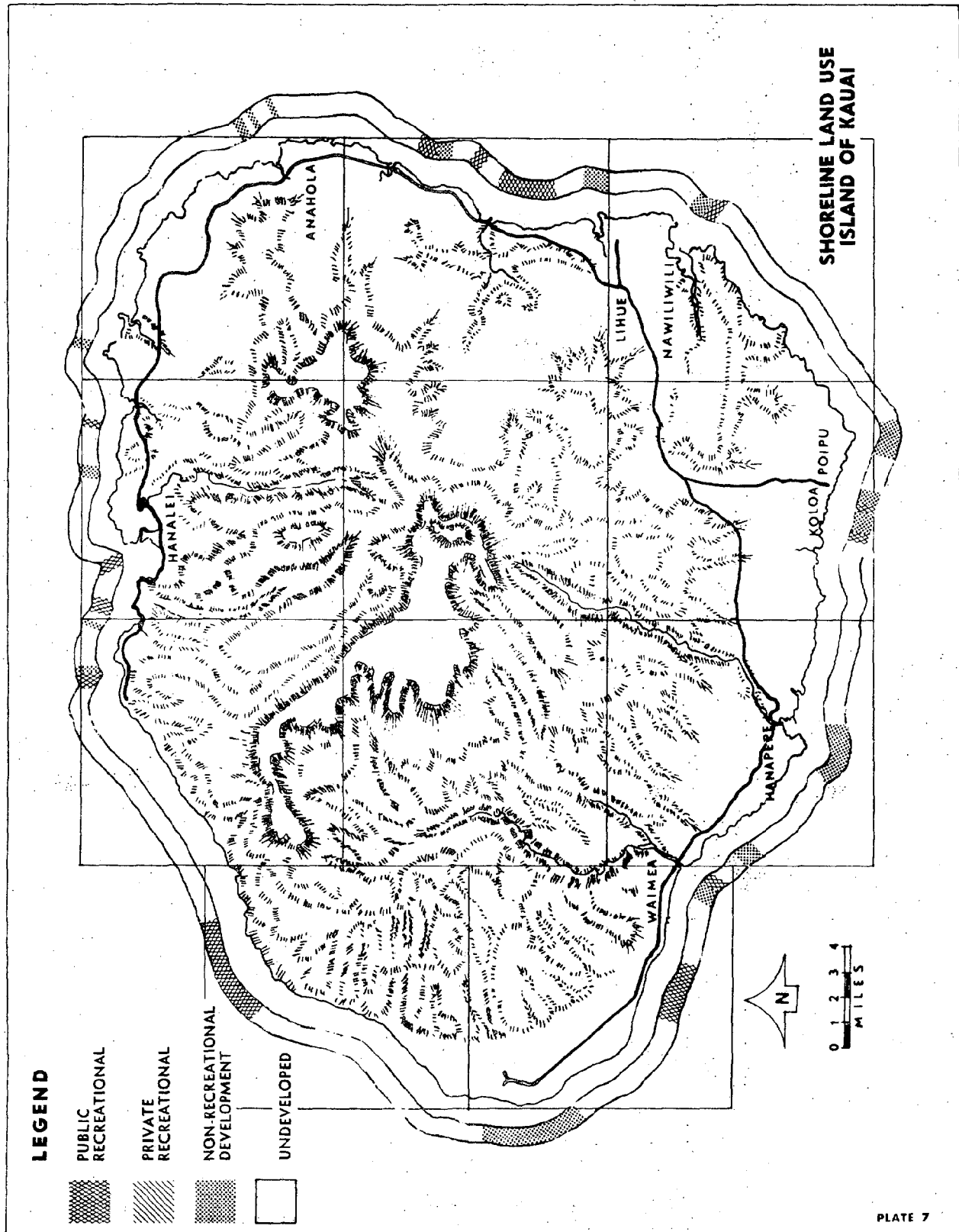
area as a result of a severe flood. By August of that year, a narrow beach zone with an erosional scarp and a narrow foreshore had returned. The offshore area of the beach is mainly sand with a few lava outcrops at each end.

The 2-mile-long sandy reach south of Wailua Bay fronts a public golf course and open land. The beach averages 75 feet in width and consists of calcareous limestone sand. Significant erosion has occurred along this reach. In some areas, as much as 30-foot-widths of shoreline have been lost.

SUMMARY

Approximately 5.0 of 113.4 miles of shoreline around the island of Kauai have been critically eroded; about 15.1 miles have a history of erosion but the problem is not critical at this time; and the remaining 93.3 miles have a history of stability or accretion.





LAND OWNERSHIP — 1962

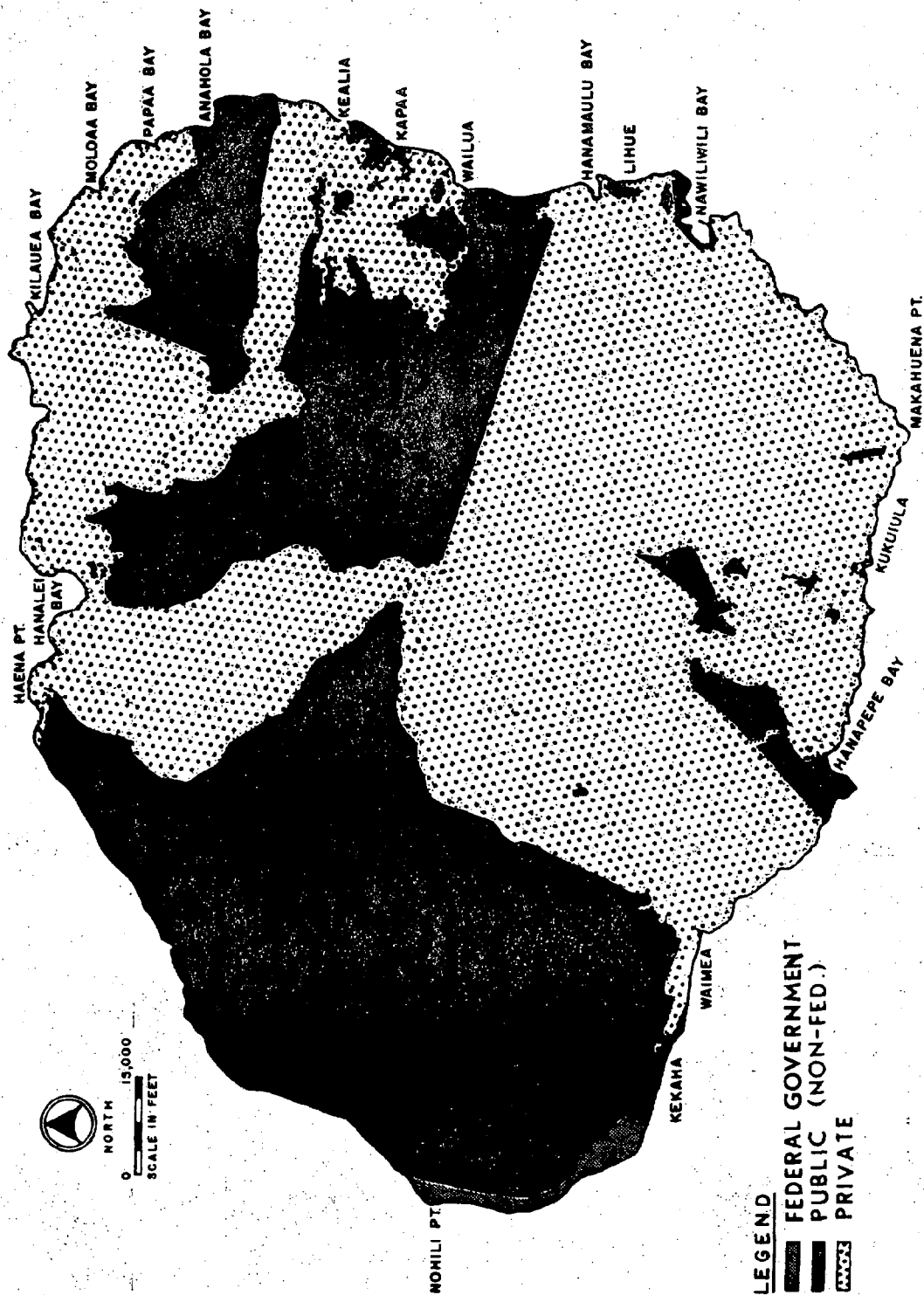


PLATE 8

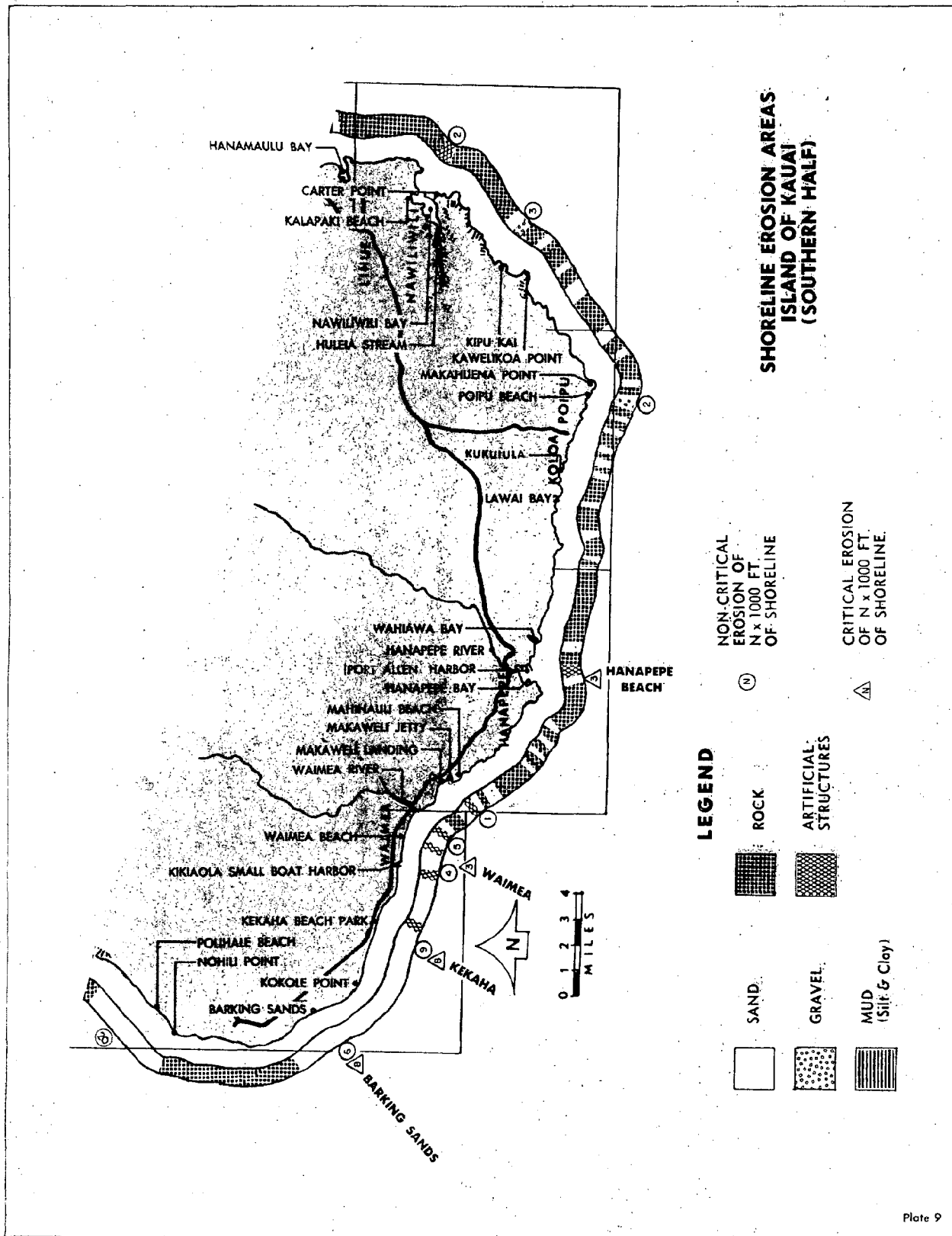
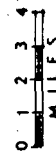
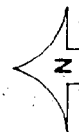
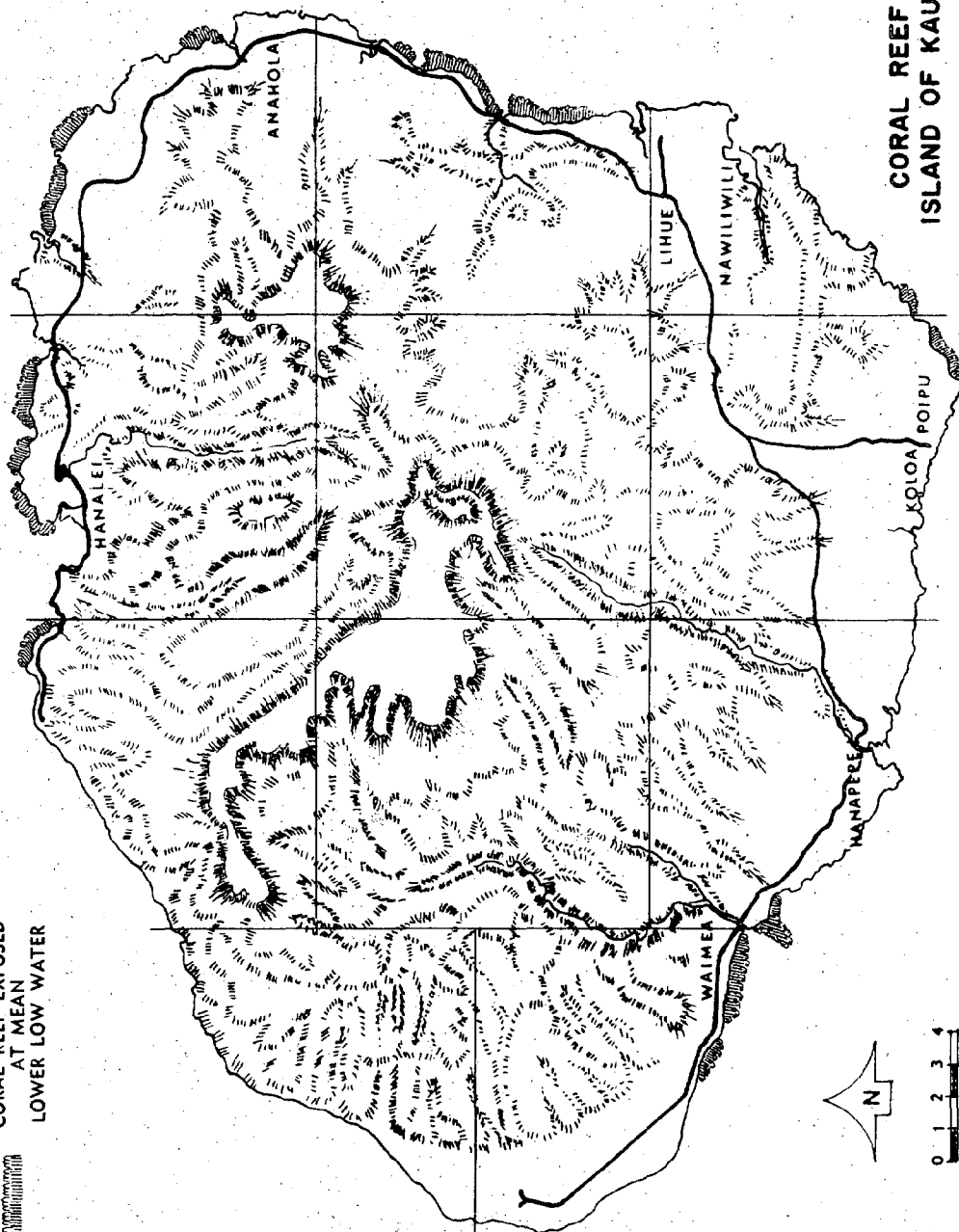


Plate 9

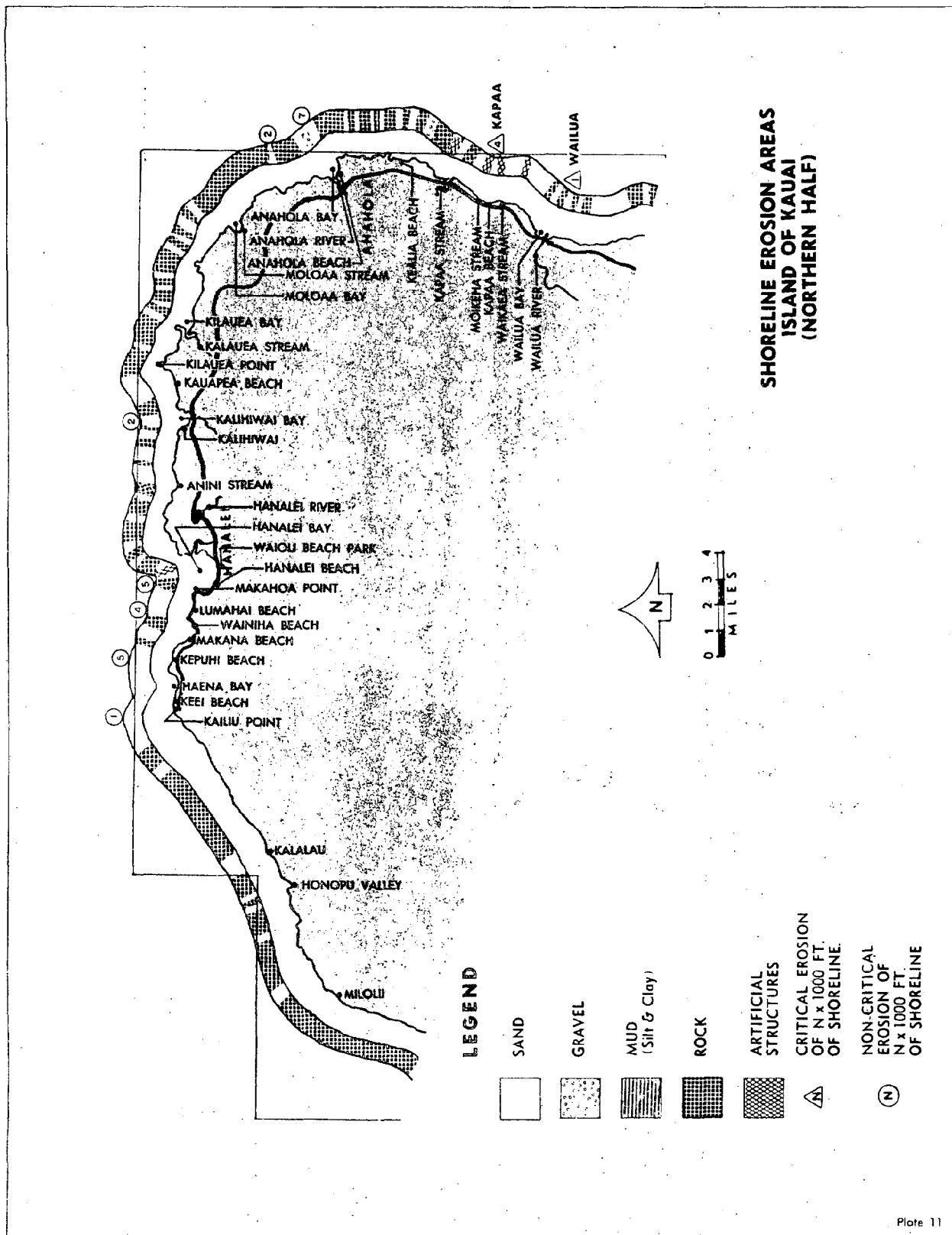
LEGEND

CORAL REEF EXPOSED
AT MEAN
LOWER LOW WATER



CORAL REEF
ISLAND OF KAUAI

PLATE 10



ISLAND OF OAHU

GENERAL

The island of Oahu has an area of 604 square miles. It is characterized by two parallel mountain ranges, the Waianae Range on the west and the Koolau Range on the east, fringing a fertile plateau. The tidal shoreline of the island is 198.5 miles long. The characteristics of this shoreline are summarized in table 7, and are shown on plate 12. Detailed descriptions are included in the paragraph on the physical characteristics and history of Oahu's shoreline.

Table 7
Shoreline Characteristics
Island of Oahu¹
(1962)

Characteristics	Miles	Percent
Rock	70.2	35.4
Gravel	8.1	4.1
Sand	55.9*	28.1
Mud (Silt and Clay)	13.4	6.8
Artificial structures	50.9	25.6
Total	198.5	100.0

¹Offshore islands excluded, except for Sand Island and Ford Island.

*Includes 5.6 miles of seasonal sand beaches where the predominant beach material is sand for only a part of the year.

Source: "Hawaii's Shoreline" prepared by the State of Hawaii Department of Planning and Economic Development in 1965.

SHORELINE USE

As shown in table 8 and on plate 13, 55.7 percent of Oahu's shoreline was in non-recreational development in 1962. Unlike the other islands, where more than half of the shoreline was undeveloped, only 25 percent of Oahu's shoreline was undeveloped in 1962. However, much of this shoreline is expected to be placed in resort and recreational use to meet the increasing recreational needs of residents and visitors alike.

SHORELINE OWNERSHIP

The shoreline around the island of Oahu constitutes 21.2 percent of the total shoreline in the state, and 27.2 percent of the state's sandy shoreline. Table 9 and plate 14 show the distribution of ownership of land abutting Oahu's shoreline.

Table 8
Shoreline Land Use
Island of Oahu¹
(1962)

Use	Total Shoreline		Sandy Beach	
	Miles	% of Total	Miles	% of Total
Recreational—Public	32.1	16.2	10.7	21.3
Recreational—Private	4.5	2.3	2.5	5.0
Non-Recreational				
Development	110.5	55.7	19.9	39.5
Undeveloped	51.4	25.8	17.2	34.2
Total	198.5	100.0	50.3	100.0

¹Offshore islands excluded, except Sand Island, Ford Island, Magic Island, and proposed reclamation of reef lands in Keehi Lagoon.

Source: "Hawaii's Shoreline" prepared by the State of Hawaii Department of Planning and Economic Development in 1965.

Table 9
Shoreline Land Ownership
Island of Oahu¹

Owner	Total Shoreline		Sandy Beach	
	Miles	% of Total	Miles	% of Total
Federal	60.9	30.7	10.2	20.3
Public (non-Federal)	41.7	21.0	12.3	24.4
Private	95.9	48.3	27.8	55.3
Total	198.5	100.0	50.3	100.0

¹Offshore islands excluded except Sand Island and Ford Island.

Source: "Hawaii's Shoreline" prepared by the State of Hawaii Department of Planning and Economic Development in 1965.

PHYSICAL CHARACTERISTICS AND HISTORY OF SHORELINE

Table 10 describes the physical characteristics, ownership, use, and condition of sandy beaches for which data are available. The following paragraphs supplement the data in the table by providing general descriptions of the physical characteristics of the entire shoreline around Oahu and qualitative assessments of shoreline conditions. The shoreline description begins at Wawamalu Beach Park and moves in a clockwise direction around the island.

South Shore (plate 15). The south coast of Oahu extending from Wawamalu Beach Park to Barbers

Table 10
Characteristics of Principal Beaches on Oahu

Name	Stability Classification Length in 1,000 Feet			Length Feet	Width Feet	Type of Beach		Predominant Beach Composition	Shore Ownership			Shore Use in Linear Feet			
	Critical Erosion	Non-Critical Erosion	Non-Eroding			Natural	Artificial		Federal	Non-Federal	Public	Private	Recreational	Non- Recreational	Undeveloped
South Shore															
Waimanalo Beach	2			1,500	100	X		Calcareous				X	2,200		1,500
Sandy Beach Park	2			2,200	100	X		"				X	1,800		
Hanauma Bay Beach Park	2			1,800	70	X		"				X			
Portlock Residential			2	2,000	10	X		"				X	1,000		2,000
Maunalua Beach Park	1			1,000	10	X		"				X			
Kaliakouon Beach Park						X		Mud Flat				X			
Wahiye Beach Park						X		Mud Flat				X			
Kahala Hilton Beach	1			1,000	50	X		Calcareous				X	1,000		
Waialeale Beach Park		1		1,000	50	X		"				X			
Waialeale-Kahala Res.	3	2		5,000	25	X		"				X	1,600		5,000
Kuilei Cliffs Beach Park		2		1,600	120	X		"				X			
Kuilei Cliffs Residential		1		2,400	25	X		"				X	100		2,100
Diamond Head Beach Park			1	100	40	X		"				X			800
Diamond Head Residential			1	800	50	X		"				X			
Waikiki															
Elks Club	1			1,000	60		X	"					1,000		
Naturalization	1			1,400	80		X	"				X	1,400		
Kapiolani Park	1			1,000	40		X	"				X	1,000		
Kuhio	2			1,500	80		X	"				X	1,500		
Royal Hawaiian-Sunrider	2			1,700	70		X	"				X			
Reef-Halekulani	2			1,500	20		X	"				X			
Fort DeRussy		2		1,800	160		X	"	X			X	1,800		
Duke Kahanamoku		1		1,000	150		X	"				X	1,800		
Ala Moana Beach Park		2		4,000	150		X	"				X	4,000		5,000
Keolu Lagoon Area		2	3	5,000	50		X	"				X			
Poahi Harbor Park						X		Mud Flat				X			
Ewa Beach Park		X		400	80	X		Calcareous				X	100		
Ewa Beach Residential		3		7,200	50	X		"				X			7,200
Oheula Beach Residential		1		1,300	50	X		"				X			1,300
Ewa Han Bush Beach Park		2		1,700	50	X		"				X			
Nimitz		1		4,000	50		X	"		X			1,700		
Barbers Point Beach Park						X		Reef Rock				X			4,000**
West Shore															
Unmanned			1	1,200	80	X		Calcareous				X	100		1,200
Kahle Point Beach Park			X	100	50	X		"				X			
Kahle Beach Opposite Hawaiian								"							
Electric Power Plant				4,000	60	X		"				X	2,000		4,000
Namakuhi Beach Park		2		2,000	100	X		"				X	9,100		
Uehaewa Beach Park		9		9,100	50	X		"				X			
Mauli Beach Undeveloped		3		3,000	100	X		"				X	2,000		3,000
Mauli Beach Park				2,000	100	X		"				X	2,000		
Lualualei Beach Park	2	2		2,000	50	X		"				X	2,000		
Lualualei Beach Park			1	1,000	100	X		"				X	1,000		2,000**
Pokai Bay Beach Park				2,000	50	X		"				X			
Pokai Military Beach				1,800	50	X		"				X			
Waianae Residential Beach		2		1,000	50	X		"				X	1,000		1,800
Maunaloa Lihalihi Beach Park		1		1,000	50	X		"				X			
Maunaloa Residential Beach		3		3,000	100	X		"				X			3,000
Maunaloa Beach Park				1,600	200	X		"				X	1,600		
Kaunua Beach Park	2			3,100	100	X		"				X	3,100		
Kaunua Beach		3		5,000	100	X		"				X			5,000
Yokohama Beach		3		3,000	100	X		"				X			3,000
**Federal															

**Federal

Table 10 continued
Characteristics of Principal Beaches on Oahu

Stability Classification Length in 1,000 Feet														
Name	Critical Erosion	Non-Critical Erosion	Non-Eroding	Length Feet	Width Feet	Type of Beach		Predominant Beach Composition	Shore Ownership Public			Shore Use in Linear Feet		
						Natural	Artificial		Federal	Non-Federal	Private	Public	Recreational	Non- Recreational Undeveloped
North Shore														
Camp Eidanah Beach		4		4,000	100	X		"			X		1,000	3,000
Mokuleia Army Beach		5		1,500	100	X		"			X		1,500**	
Mokuleia Au Force Beach		5		5,000	100	X		"		X				5,000
Mokuleia Residential Beach	10			20,000	75	X		"						20,000
Mokuleia Beach Park		1		1,400	75	X		"		X			1,400	
Haleiwa Residential Beach	1			2,000	100	X		Calcareous						2,000
Haleiwa Army Beach		X		300	100	X		"		X			300**	
Waialua Beach Park		2		1,800	100	X		"		X			1,800	
Haleiwa Beach Park		2		1,800	100	X		"		X			1,800	
Kaunaloa Residential Beaches	2			5,000	100	X		"		X			400	5,000
Waimea Beach Park		X		400	150	X		"		X				
Waimea Undeveloped Beach		1		1,400	150	X		"		X				
Pupukea Beach Park			3	3,400	200	X		"		X			3,400	1,400
Sunset Residential Beaches	6			12,000	200	X		"		X			800	12,000
Elukani Beach Park		1		2,800	200	X		"		X				
Sunset Undeveloped Beach		2		2,300	200	X		"		X				2,300
Waialeale Residential Beach	1			2,500	100	X		"		X				2,500
Waialeale Beach		5		5,000	70	X		"		X				5,000
Kaunaloa Bay Res. Beaches	2			1,500	70	X		"		X				1,500
East Shore														
Kahuku Golf Course Beach		2		4,000	100	X		"		X			4,000	
Makaha Pt. to Lanika Pt.		4		8,000	70	X		"		X				8,000
Residential Beaches		4		9,000	70	X		"		X				9,000
Lanika Pt. to Hauula	1			2,000	40	X		"					2,000	
Hauula Beach Park	2			9,000	50	X		"		X				9,000
Hauula to Punaluu		2		1,500	40	X		"		X				1,500
Residential Beaches		2		4,000	40	X		"		X				4,000
Kahana Bay Beach Park		2		2,100	100	X		"		X			2,100	
Swanzy Beach Park	1			1,000	40	X		"		X			1,000	
Kaunaloa Residential Beaches	1			2,300	40	X		"		X				2,300
Kaunaloa Beach Park	2			1,700	40	X		"		X			1,700	
Kalaheo Beach Park		X		300	80	X		"		X			300	
Roadside Beach		3		3,300	80	X		"		X				3,300
Kualoa Res. Sandy Beach		2		8,000	80	X		"		X				8,000
Kualoa Undev. Sandy Beach		8		—	—	X		Mud Flat		X				1,500
Waialeale Beach Parks		—		—	—	X		Mud Flat		—				
Lanikai Beach Park & Kahala		—		—	—	X		Mud Flat		—				
Kaunaloa Beach Park	1			3,000	100	X		Calcareous		X				3,000
Mokapu Marine Corps Beach	3			2,800	150	X		"		X			2,800	
Kaula Residential Beach		3		7,000	60	X		"		X				7,000
Lanikai Residential Beach	3			3,500	100	X		"		X			5,500**	
Bellows Mt. Beach Park	2			2,500	50	X		"		X				
Bellows Mt. Semi-Pub. Beach		7		8,000	150	X		"		X				
Waimanalo State Beach		3		2,000	50	X		"		X				
Waimanalo Beach Park		8		3,300	50	X		"		X				2,000
Waimanalo Residential Beach		2		900	100	X		"		X				
Kaunaloa Beach Park		3		—	—	X		"		X			3,300	
Makapu Beach Park		1		—	—	X		"		X			900	

**Federal

Point is generally low, thereby affording relatively easy access to most parts of the shoreline. The southern exposure and stretches of fringing reefs (plate 16) provide reasonable protection against damaging effects of storm waves and tsunamis. The location of Honolulu, the largest urban development in the State; the largest civilian and military ports; and a large share of the armed forces establishments along this coast make it the most important coastal reach in the state.

The reach between Wawamalu Beach Park and Diamond Head is characterized by rocky coasts and protective structures with only a few short reaches of sandy beach. The shoreline from Wawamalu Beach Park to Halona Point consists of 1,500- to 2,200-foot-long reaches of about 100-foot-wide sandy beaches between stretches of lava basalt outcrops. The beaches are quite steep and front an area of low dunes covered by grass and kiawe trees.

Except for Hanauma Beach Park, the coastline from Halona Point to Maunaloa Bay is an extremely rocky, terraced sea cliff affording only marginal accessibility (figure 6). The 1,800-foot-long, 30-to 100-foot-wide sandy beach at Hanauma Bay had been eroding to the extent that coconut trees about 20 feet inland from the shoreline were being undermined (figure 7). In April 1970, the City and County of Honolulu, Department of Parks and Recreation, initiated remedial action for the beach park. The beach erosion control project consisted of construction of a wave barrier, restoration of the beach (figure 8), and excavation of a new swimming area.

The shoreline of Maunaloa Bay has been considerably altered by artificial structures which include a boat launching ramp, seawalls along the residential area at the east end of the bay and coral fill which was placed along the center section during initial development of a marina-oriented residential area in



Fig. 6 Rocky coastline between Hanauma Bay (lower left) and Wawamalu Beach Park (upper left), Oahu

the valley behind the bay (figure 9). The coral fill area is part of the Maunalua Beach Park, and is fronted by a 1,000-foot-long 10-foot-wide sand beach which is gradually eroding. The offshore area of the bay is characterized by one of Hawaii's shallowest reefs. Relatively few organisms appear to be living on this reef-flat where local patches of sand have been observed.

The shoreline in the Kuliouou area at the west end of Maunalua Bay is largely a mudflat up to Paiko Peninsula, after which it is an almost continuous stretch of seawalls with narrow, poorly sorted gravel and sand beaches fronting them. Except for two 1,000-foot-long, 50-foot-wide sand beaches, one of which is artificially constructed, the seawalls extend to Black Point, a rocky headland formed when lava from a late eruption flowed seaward across the reef. The seawalls at Niu and Wailupe peninsulas within this reach border on ancient Hawaiian fishponds which have been filled and developed into residential areas.

Erosion has occurred along a 3,000-foot-long reach within the Wai'alae-Kahala residential area which extends from Wailupe Peninsula to Black Point. Erosion in this area has undermined steps, seawalls, and beachfront property. Erosion has also occurred along the artificially constructed sand beach fronting a resort hotel in the Kahala area. The erosion reduced the recreational usefulness of this beach and necessitated periodic beach nourishment which has been accomplished by private interests (figure 10).

From Black Point westward around Diamond Head, stretches of rocky coast on which are cut a terrace about five feet above sea level alternate with narrow beaches of fine- to medium-sized coral fragments (figure 11).

The shoreline from Diamond Head to Pearl Harbor is primarily artificial, the result of extensive dredging of reef areas, construction of artificial structures, and filling of former mudflats, fish and duck ponds, and shallow reef areas. These lowlands are the urban areas of the city of Honolulu and support a concentration of industrial and commercial facilities as well as recreational, resort and residential areas.

Over 10 million visitations by swimmers, surfers, sunbathers and other beach users are estimated to have occurred at Waikiki Beach in 1970. It is probably the most well known surfing beach in the world (figure 12). This two-mile stretch of shoreline extending from the west end of Diamond Head to the Ala Wai Yacht Harbor, was formerly a barrier beach fronting swamps and duck ponds. This beach is now almost entirely artificial with imported sand, groins and seawalls along most of the reach (figure 13). Alteration of the shoreline resulted primarily from attempts to reduce beach erosion which date back to the early 1900's. Since that time, numerous remedial

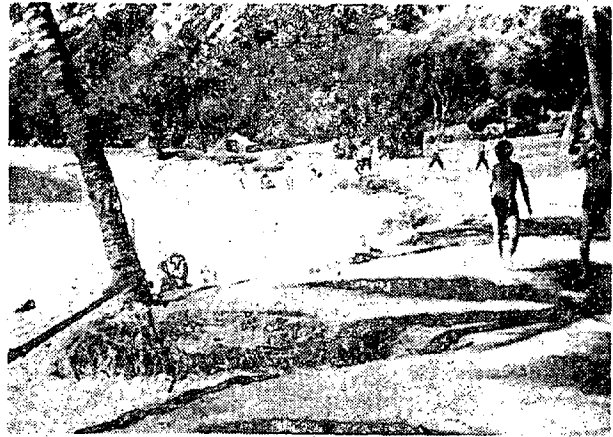


Fig. 7 Undermined coconut tree at Hanauma Bay Beach Park



Fig. 8 Restoration of the beach at Hanauma Bay Beach Park, Oahu.



Fig. 9 Maunalua Bay area, Oahu

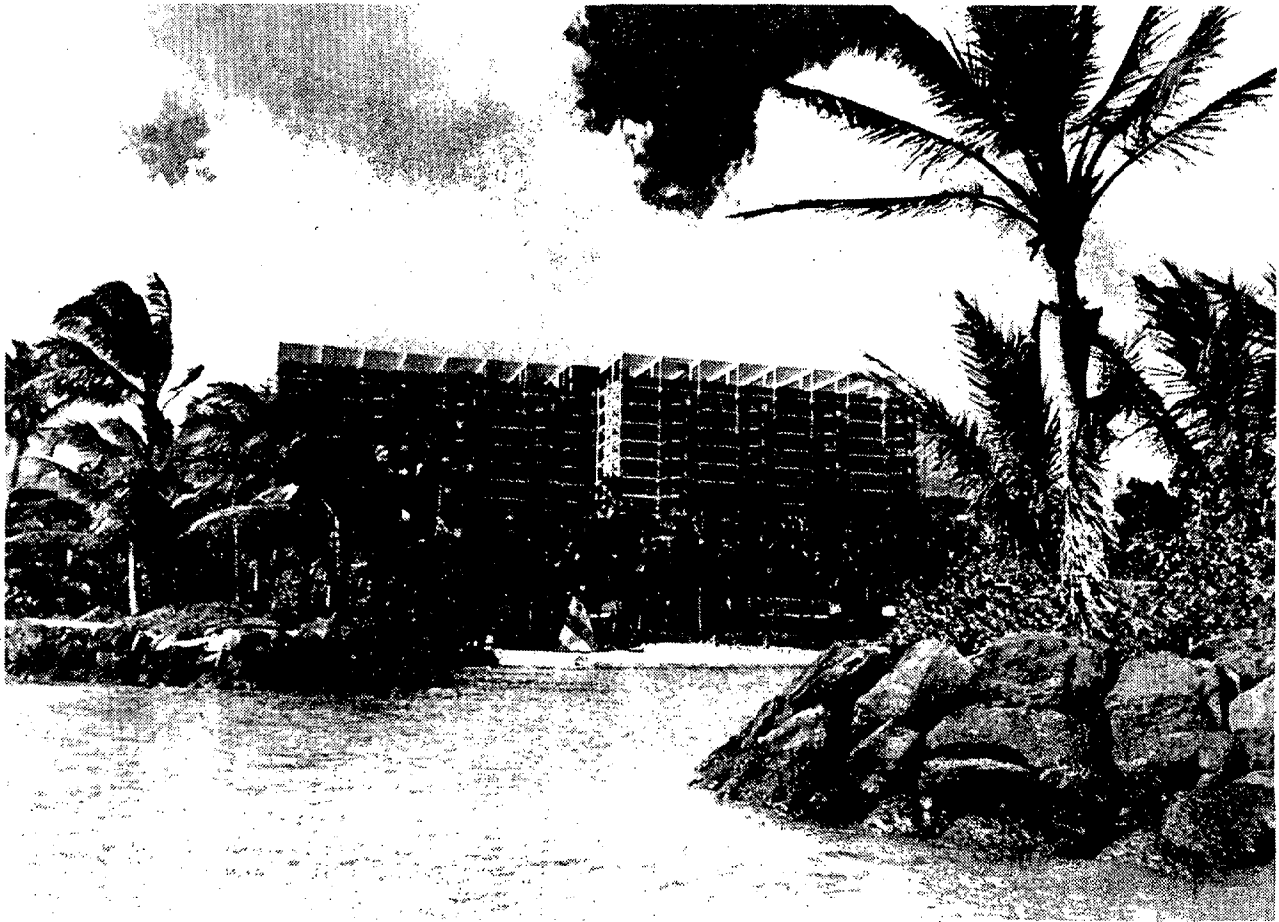


Fig. 10 Kahala Hilton Beach, Oahu (Camera Hawaii Photo)

actions have been independently pursued by various interests, including property owners, the City and County of Honolulu, the State of Hawaii, and the Federal Government. Remedial measures have included construction of a variety of structures such as seawalls, cribwalls, and rubblemound and sandbag groins. The effectiveness of these structures vary; however, the net effect has been minor, and erosion is still a problem at this beach. The severity of the problem is exemplified by a brief history of Kuhio Beach, a 1,500-foot-long reach in the center of Waikiki Beach. Action taken in May 1939 to curb erosion at this beach resulted in placement of a 150-foot-wide beach. However, within eight years, a section of the beach was completely denuded. Action taken by the Territory of Hawaii in 1951 resulted in, among other things, placement of a 150-foot-wide beach. However, erosion has continued to occur, so that the existing beach varies in width from 0 to 230 feet (figure 14). The remaining reaches of this famous

two-mile-long beach vary in width from 0 to 150 feet, except at the Ft. DeRussy military beach at the west end. Although this beach was once from 0 to 50 feet wide, it has recently been improved by the Corps of Engineers, and now has an average width of 160 feet above mean lower low water.

The artificially constructed Duke Kahanamoku Beach adjacent to Ft. DeRussy comprises the western limit of Waikiki Beach. Constructed in 1956, this recreational beach consists of a 1,000-foot-long, 150-foot-wide sandy beach area, a 7-foot-deep, 150-foot-wide offshore swimming area, and a 6-acre lagoon landward of the beach (figure 15). The sandy beach is protected by two groins, one at each end of the beach. Although some loss of sand occurred during the first few years following completion of the beach, this was attributed to the natural process of a beach reshaping to conform with the prevailing wave front. After the reshaping by wave action, the beach stabilized to its present crescent shape, and sand loss has been minor.

The Ala Wai Boat Harbor immediately west of Duke Kahanamoku Beach is the largest and finest light-draft vessel harbor in the state with a berthing area of about 31 acres and slips for about 515 craft (figure 16). Construction of this harbor in 1935 altered the natural shoreline by dredging of an entrance channel and small basin in the wide, shallow, fringing reef. Since that time, many improvements have been made by the State of Hawaii. The existing harbor consists of a 1,700-foot-long breakwater, 2 interior moles, 1 wooden T-pier and a 200-foot-wide, 1,400-foot-long entrance channel.

Ala Moana Beach Park, the finest and most popular beach park in urban Honolulu, lies between the Ala Wai Boat Harbor and Kewalo Basin Light-Draft Harbor. The 4,000-foot-long, 150-foot-wide beach at Ala Moana is primarily artificial. Magic Island at the east end of Ala Moana Park is a manmade peninsula which was completed in 1964 through reclamation of about 30 acres of shallow reef (figure 16).

The manmade light-draft harbor at Kewalo Basin was constructed in 1945 by dredging of the coral reef to provide for the berthing basin and entrance channel. The existing harbor is approximately 800 feet wide, 1,000 feet long, and 20 feet deep (figure 17). The entrance channel at the southwest corner of the harbor basin is 200 feet wide, 1,200 feet long, and 20 feet deep.

Honolulu Harbor, the largest civil port in Hawaii and the only commercial deep-draft harbor on Oahu, was originally developed in the late 1700's in a natural protected harbor approximately 7 miles east of Pearl Harbor. Roughly crescent shaped, the harbor is approximately two miles long and varies in width from 600 to 2,900 feet. The existing harbor has been extensively expanded from its original configuration by dredging of berthing areas into the natural shoreline and construction of pier and other harbor-related structures along the entire shoreline fronting the harbor complex. Sand Island, a 500-acre manmade island which protects the harbor from the open sea, was created on the shallow reef offshore from the harbor by deposition of spoil material from dredging operations over the years. The topography of the harbor complex, including Sand Island, is relatively flat with ground elevations ranging from 0 to 10 feet above sea level.

The reach extending from Honolulu Harbor to Pearl Harbor is characterized by a military reservation and a civilian industrial area which includes the Honolulu International Airport complex. The shoreline fronting this reach is primarily mudflats and gravel beaches. The two sandy beaches within this reach are within the military reservation. Artificial structures line a 2,500-foot reach immediately west of Honolulu Harbor and a 4,000-foot reach fronting the international airport complex.



Fig. 11 Rocky coastline around Diamond Head, Oahu



Fig. 12 Surfing on Waikiki Beach, Oahu (Camera Hawaii Photo)

Most of the shoreline between Pearl Harbor and Barbers Point is in military reservation, which includes a U.S. Air Force base, the U.S. Navy's Pearl Harbor complex, and its air station at Barbers Point (plate 15). Much of the shoreline within Pearl Harbor has been altered to provide for berthing and shipyard facilities. Other areas within the harbor are either mudflats or gravel beaches. Other than the harbor area, the shoreline consists of alternating stretches of rocky and sandy shoreline. Along parts of the rocky areas, sand can be found immediately inland of the water-level beachrock. The primary sandy beach areas are at Ewa Beach, Oneula, and artificially constructed Nimitz Beach.

The 400-foot-long, 80-foot-wide beach at Ewa Beach Park consists of medium- to coarse-grained, poorly sorted, and predominantly calcareous sand. The foreshore is usually quite steep and sometimes supports a berm of gravel resulting from storms. Erosion has occurred at this beach, but is confined to the west of the park and is considered minor.

A 7,200-foot-long beach fronts the residential area west of Ewa Beach Park. Although the beach has an average width of 50 feet, it tapers in width to sections where the shoreline consists of seawalls. Erosion which has occurred along a 4,000-foot-long section is considered significant from the standpoint of property losses.

Oneula Beach west of Ewa Beach is approximately 3,000 feet long and 50 feet wide. Sand on this beach consists of moderately well sorted, medium sized grains of calcareous origin. However, short reaches of low ridges of calcareous gravel also occur along this beach which generally has a level backshore which is built to a sharp berm crest and then to a steep foreshore.

Nimitz Beach, a military beach park fronting the Barbers Point Naval Air Station, is approximately 4,000 feet long and 50 feet wide. The beach was artificially constructed and consists of medium to coarse grains of calcareous origin.

West Shore (plate 15). The 25-mile-long reach from

Barbers Point to Kaena Point is characterized by a hinterland of broad, arid valleys alternating with steep-sided ridges; by a shoreline of rocky stretches alternating with stretches of excellent beaches, and by an offshore area of very narrow reefs with a steeper descent to waters of a few hundred fathoms than is characteristic of any other coast on Oahu. Development along this shoreline consists of military reservations, homestead lands, and rapidly expanding residential and resort areas. This shoreline supports a total of 12 beach parks, two of which are military parks and the remaining 10 of which are public parks.

The rocky shoreline consists of either beachrock, outcrops of Waianae basalt bedrock or raised coral reefs which have created terraces 5 to 10 feet above sea level. Beaches in this area are from about 1,000 to 5,000 feet long, about 100 feet wide, and are generally composed of medium to fine grains of calcareous material. Except for the beach at Pokai Bay, which is protected by a breakwater, the beaches in

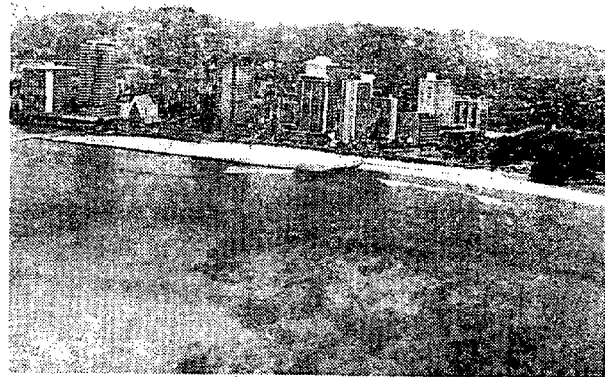


Fig. 14 Eroded conditions of the Kuhio Beach sector of Waikiki Beach

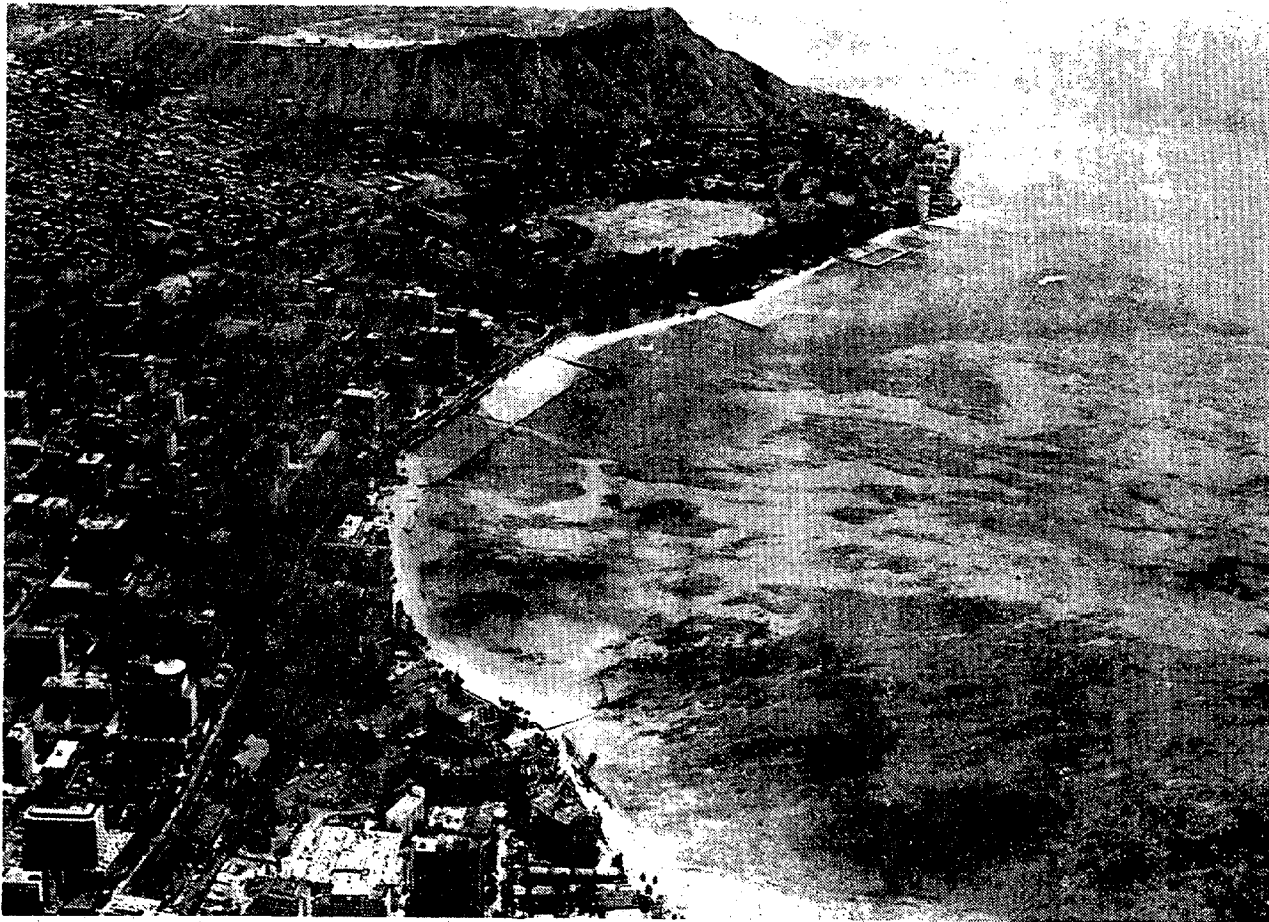


Fig. 13 Aerial view of Waikiki Beach

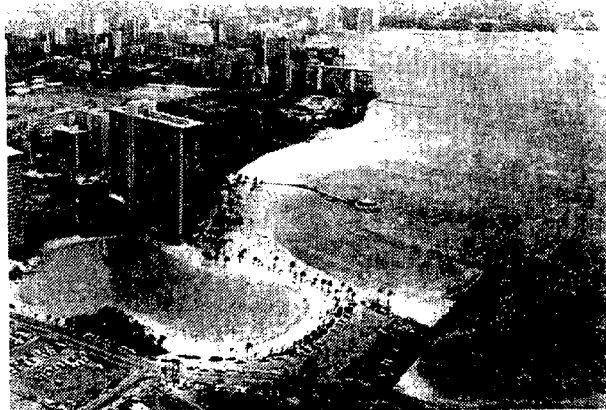


Fig. 15 Man-made Duke Kahanamoku Beach

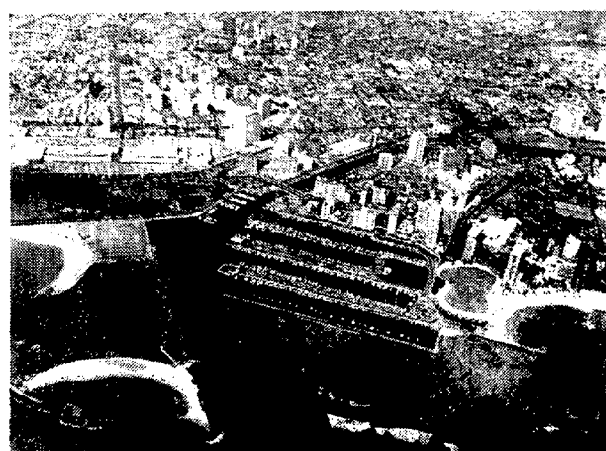


Fig. 16 Aerial view of Ala Wai Boat Harbor and Magic Island, Oahu



Fig. 17 Aerial view of Kewalo Harbor, Oahu

this area have steep foreshores, pronounced seasonal changes, and dune ridges.

A barge harbor near Barbers Point, a breakwater and launching ramp at Pokai Bay, and a few short stretches of seawalls are the only artificial structures along this shoreline. Privately developed, the Barbers Point barge harbor serves a 1,300-acre industrial complex immediately west of the Barbers Point Naval Air Station. The harbor was completed in 1961 by excavating and dredging an L-shaped area on the flat coral coastal plain. Dimensions of the basin are approximately 520 by 700 feet. The entrance channel, including the offshore portion, is 1,300 feet long and 220 feet wide. Additional alteration of the shoreline adjacent to the barge harbor would result from construction of the proposed Barbers Point Deep-Draft Harbor which was authorized by the Congress under the River and Harbor Act of 1965. Engineering plans for the harbor are being developed by the Corps of Engineers.

Except for significant erosion at the public park at Maili Beach and the military park at Pokai Bay, the reach between Barbers Point and Kaena Point is characterized by seasonal erosion and accretion. The erosion which occurred along a 2,000-foot-long reach of Maili Beach Park during the winter of 1968-69 undermined an outdoor shower facility and jeopardized the stability of the park's comfort station. This was the most severe incident of the erosion which has been occurring at this beach as evidenced by the vegetation line which has receded about 50 feet during the last 20 years.

Erosion along the center section of the beach fronting the military beach park at Pokai Bay has undermined a retaining wall and endangered several adjacent structures. This erosion, which is reducing the recreational usefulness of the beach, is confined to the center section. The northern section is relatively stable and the southern section is accreting. Remedial action was taken on several occasions by Army Reserve units who transferred some of the sand from the accreted southern section to the denuded center section of the beach.

North Shore (plate 17). This 24-mile-long reach extends from Kaena Point to Kahuku. The main coastal features of this reach are the strong winter surf and the irregular reef. Storm swells which usually originate in the vicinity of the Aleutian Islands often cause extreme surf conditions which inflict severe damage to the beaches and beachfront properties along this coastal reach. These storms usually occur during the winter months. During the summer, the beaches usually accrete, and are among the widest and best beaches on the island. Except for a military airfield and park, most of this reach is in agriculture, recreational beach parks, and residential developments.

The 3-mile-long shoreline immediately east of Kaena Point is a platform cut into lava basalt near existing sea level. Generally, this reach is covered with boulders and cobbles, but there are several stretches of sand beaches and a few tiny pocket beaches. This reach is followed by a 6-mile-long reach known as Mokuleia Beach. The shoreline along this reach is predominantly sandy beach with a few scattered areas of exposed beachrock behind which are found pockets of sand. There are extensive dune ridges along this reach. Some of the dune sand has been excavated for commercial purposes. Most of the dunes are stable, but some at the west end are active. Critical erosion has occurred along a 2-mile reach of Mokuleia Beach. This reach was also severely damaged during the storm of December 1-4, 1969. High waves damaged structures and inundated property as far as 250 feet inland from the shoreline.

The hinterland of the reach extending from Mokuleia Beach to Haleiwa Beach Park is a gentle coastal plain which slopes inland to a saddle between

the Koolau and Waianae Ranges. This area contains a large sugar plantation and the contiguous small towns of Waialua and Haleiwa.

The shoreline along this reach has two bays and alternating reaches of sandy beaches and rock outcrops. The only significant alteration of the natural shoreline along this reach is at the Haleiwa Boat Harbor at the west end of Waialua Bay (figure 18). As directed by the United States Congress, the Corps of Engineers completed the Federal portion of the harbor in 1966. This portion consisted of a 610-foot-long, 120-foot-wide, 12-foot-deep entrance channel; a 1,200-foot-long revetted mole; a 520-foot-long, 80-foot-wide diversion channel for the Anahulu River; and a 7.4-acre protected harbor area. The State portion of the harbor was completed in 1967, and consisted of dredging of a berthing area; construction of 20 catwalks to accommodate 40 boats and a marginal wharf adjacent to the launching ramp; paving of the area behind the catwalks and marginal wharf; and installation of utilities.

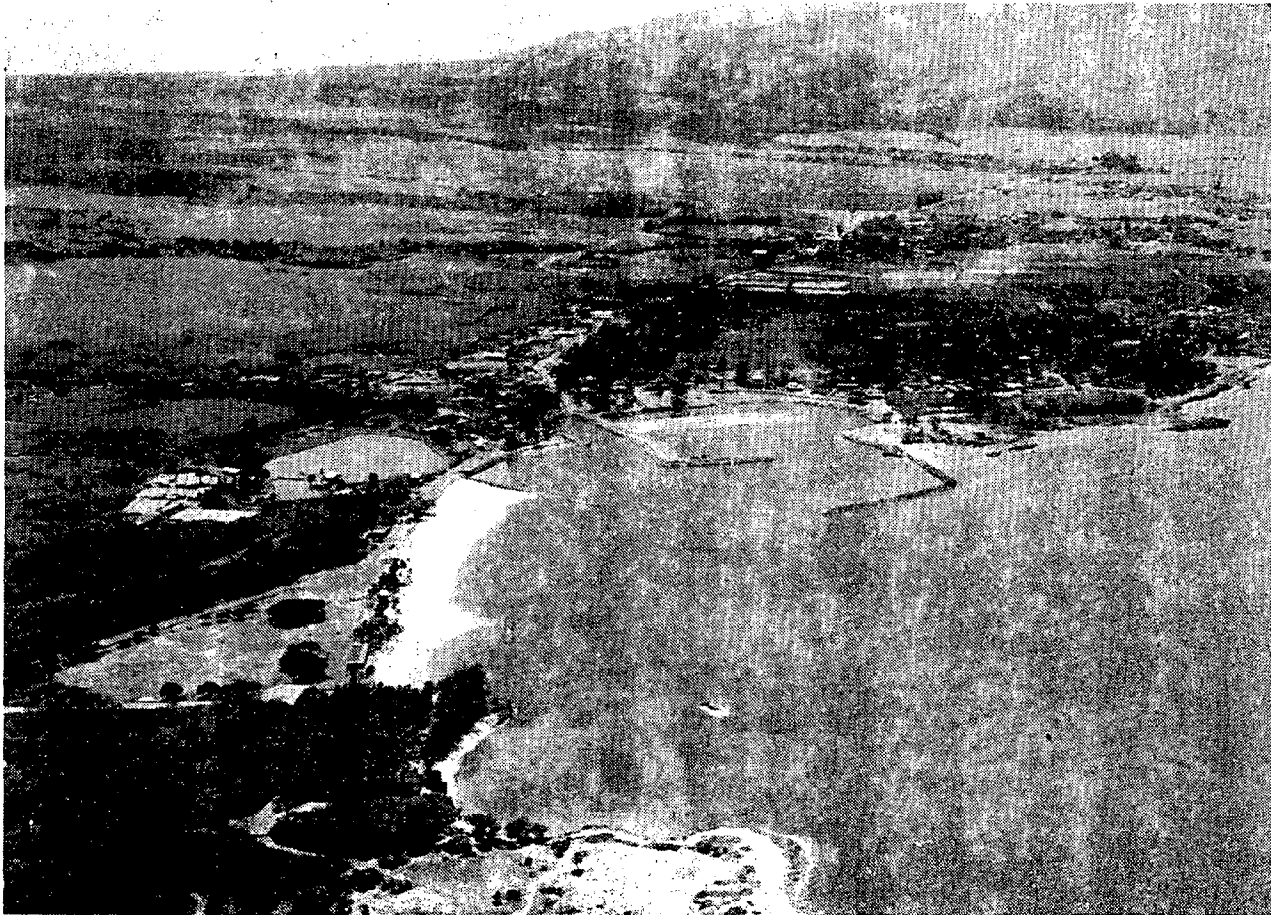


Fig. 18 Aerial view of Haleiwa Harbor and Haleiwa Beach Park, Oahu.

Haleiwa Beach Park, which lies immediately east of the boat harbor, has experienced critical erosion. In December 1949, the entire shoreline from the north end of the park to the mouth of the Anahulu River was fronted by an excellent sand beach which ranged in width from approximately 90 to 130 feet above mean lower low water. However, during the early 1950's gradual erosion was observed. This erosion continued, and by December 1965 the beach fronting a section of the park had eroded to within two feet of a seawall which collapsed two months later. On March 9, 1957, a large volume of sand was lost due to a tsunami which originated in the Aleutian Islands. The severity of continued erosion of this beach justified Federal participation in a beach erosion control project which was completed in 1965, and resulted in, among other things, a 1,600-foot-long beach with a width varying from 140 to 265 feet above the mean lower low water line (figure 18). However, this beach, as well as the adjacent small boat harbor, was again severely damaged during the storm of December 1969. Sections of protective structures such as breakwaters and groins were damaged and approximately 7,000 cubic yards of sand were lost. As a result, the State of Hawaii requested Federal participation in emergency repair work for the beach park and small boat harbor. In November 1970, the Corps of Engineers completed repair of the damaged groins and offshore breakwater, and placement of about 7,000 cubic yards of sand over the eroded sections of the beach.

Kawailoa Beach, a two-mile reach extending east from Haleiwa Beach Park, consists of alternating stretches of sandy beach and outcrops of lava and beachrock. The beach is predominantly medium grains of highly calcareous sand. It changes seasonally and experiences up to 40 feet of erosion during the winter. During the last few years, erosion along a 2,000-foot-long reach has encroached on residential property to the extent that remedial measures are required. The high waves during December 1-4, 1969, resulted in considerable loss of sand, structural damages, and loss of property (figure 19).

Waimea Bay, which lies east of Kawailoa Beach, is flanked by wide expanses of rocky shoreline, mainly lava basalt. The most important of the few river-mouth barrier beaches on Oahu lies at the head of this bay. This slightly arcuate pocket beach is about 1,800 feet long and 150 feet wide. The width of the beach varies seasonally, with sand from the southwest end moving to the northeast end during the winter, then moving back during the summer. Some sand also moves offshore during the winter. The beach has a steep foreshore during the winter and a flat one during the summer. The sand is well-sorted, medium-sized grains of calcareous origin, and had been extensively mined for commercial purposes up



Fig. 19 Damage to a section of the coastal highway along Kaiwailoa Beach, Oahu

to about 1965. The beach is now a popular public beach park, although swimming during the winter is extremely dangerous because of high waves and strong rip currents in the bay.

Sunset Beach, a two-mile-long reach east of Waimea Bay, is the longest wide beach on Oahu. Although outcrops of beachrock and raised reef are seasonally exposed at the waterline, the sand behind them is continuous and averages about 200 feet in width. Severe erosion occurs during the winter, resulting in a steep foreshore. However, during the summer the foreshore slope is relatively gentle. The sand along this reach is poorly sorted, medium- to coarse-sized grains of calcareous origin. Erosion during the past two years has endangered beachfront property along half of this reach and is considered critical. Erosion along the remaining half of this reach is not considered to be of significance at this time. This reach was also severely damaged by the storm of December 1-4, 1969.

A broader coastal plain characterized by hills of old, lithified sand dunes and marshy lowlands extends from Kawela Bay to Kahuku. The shoreline along this reach is predominantly rocky. In general, points of land along this irregular coast are of raised reef limestone between extensive developments of beachrock. There is considerable sand near the shore, but except for beaches near Kawela Bay, most of the sand is in active and stabilized dunes or in storm beaches which are beaches created immediately inland of rock outcrops by storm-deposited sand.

East Shore (plate 17). The 52-mile-long eastern or windward coast of Oahu is characterized by relatively wide reefs and tradewind-generated waves. This reach extends from Kahuku to Makapuu Point and consists of agricultural and residential developments, and several public parks.

The northern third of the east shore extends from Kahuku to Kalae-Oio Beach Park, and is characterized by a narrow coastal plain between the sea and the east flank of the Koolau Range. Developments along this reach are primarily agricultural and residential, and include six public parks. Although sandy beaches front much of this coastal reach, they are all very narrow except for those at Kahuku and Kahana Bay. Part of the coast, particularly sections at Punaluu and Kahana Bay, consists of boulders and cobbles. Seawalls which are common along parts of this coastal reach were constructed in an effort to protect beach-front property from erosion.

A 4,000-foot-long reach fronting a golf course in Kahuku has an average width of 100 feet and consists of sand and bedrock. The reach extending from Makahoa Point south of the golf course to Laniloa Point consists of two bays with beaches averaging 70 feet in width. The first, an unnamed crescent shaped bay, is composed of calcareous, moderately well sorted, fine grains of sand. Rock is exposed at the shore near the north end of the bay, and a small patch

of beachrock is exposed in the middle of the beach. There is no berm development, but a sandy, vegetated terrace is indicative of an old berm. The terrace is bordered on the landward side by a vegetated old dune ridge on which houses are built.

Laie Bay, immediately south of the unnamed bay, is convex seaward at the center and broadly concave seaward on both sides. The beach has a relatively steep foreshore, although a small berm occasionally develops. The sand is well sorted, medium-sized grains of calcareous origin.

A narrow but attractive beach fronts a shallow unnamed bay in the center of the reach extending from Laie to Hauula. The beach is slightly arcuate, with a small rocky point to the north and a broad, rocky and sandy point to the southeast. The sand is poorly sorted, medium to coarse grains of calcareous material. The head of a large, steep-walled, sand-bottomed channel lies close to shore in the middle section of the bay. The reef off the south part of the beach is very wide and shallow.



Fig. 20 Aerial view of Hauula Beach, Oahu

The fairly straight but narrow beach fronting the public park at Hauula is 2,000 feet long and 40 feet wide (figure 20). There is no berm along this beach which has a moderately steep foreshore. The sand is composed of fairly well sorted, medium-sized grains, about four-fifths of which are of calcareous material. Erosion since 1935 has claimed an average of 14 feet of beach along a 1,400-foot reach. In November 1969, the top of the beach slope along the northern end of the park was within 5 feet of an adjoining highway right-of-way. Toward the southern end of the park, the top of the beach slope was within 3 feet of the park pavilion which houses a concession stand and bathhouse. The top of the slope along the central section extended along a line of 14 ironwood trees which have been partially undermined by erosion.

The reach from Hauula to Kahana Bay is characterized by very narrow beaches. Seawalls which are common along this reach were constructed to protect beachfront property and the coastal highway from erosion.

The 3,000-foot-long shoreline fronting the Punaluu Beach Park has been severely eroded. The shoreline along the northern half of the park consists of cobbles, boulders, and very little sand. Prior to 1955, large boulders were dumped along this sector in an effort to protect the shoreline. A 40-foot-wide sandy beach fronts the southern half of the park. The beach is relatively flat and composed of poorly sorted, medium to coarse grains of calcareous sand. It was severely eroded during the winter storms of 1968-69.

Artificial structures along the north and south sides of Kahana Bay flank a crescent-shaped barrier beach at the head of the bay. The artificial structures consist of a boat launching facility on the north shore and an ancient Hawaiian fishpond along the south shore. The 100-foot-wide barrier beach fronts a public beach park. The beach has a relatively flat slope and is composed of poorly sorted, medium to fine grains of calcareous limestone. A very shallow reef exists on the south side of the bay, and a sand-bottomed channel leads out from the center. Sand in this channel, one of the largest on Oahu, is more than 15 feet deep.

A very narrow gravel beach extends from Kahana Bay to Swanzy Beach park. The landward limit of the shoreline fronting Swanzy Beach Park is defined by a vertical masonry seawall. At mean low water, the beach seaward of the wall is about 20 to 30 feet wide. Cobblestones comprise the bulk of the beach material which ranges in size from sand to small boulders. A shallow coral reef extends about 1,500 feet seaward of the beach and is estimated to underlie the beach at an elevation of about -2 feet MLLW. The winter storms of 1968-1969 severely damaged the beach and undermined the protective seawall. Accretion which has historically occurred at this beach during summer months did not occur during the sum-

mer of 1969 to alleviate the damage from erosion during the previous winter.

The 1,700-foot-long, 40-foot-wide beach at Kaaawa Beach Park has been subject to erosion over the years (figure 21). Since early 1962, from 40 to 60 feet of land has been lost due to erosion along the entire length of the beach. High waves during December 1968 and January 1969 were particularly damaging, and caused undermining of numerous coconut trees as well as the park's comfort station. In December 1968, the City and County of Honolulu Department of Parks and Recreation dumped rocks around many coconut trees, the comfort station, and along a portion of the beach berm as an emergency measure to retard erosion. Construction of a new pavilion-bathhouse was postponed because of the severity of the erosion problem.

Protective rock revetment lines the shoreline between Kaaawa Beach Park and Kalae-Oio Beach Park. These structures were constructed to protect the coastal highway from erosion. There is little or no beach seaward of the structures and waves run up very close to the revetment. The beach at Kalae-Oio Beach Park is 300 feet long and 80 feet wide, and is composed of sand of calcareous origin.

The increased usage of beach parks along the east shore and the increased demand for residential construction along these shores have focused attention on the erosion problems in this area. Erosion at four of the six public beach parks is considered critical from the standpoint of the effect on the recreational usefulness of these beaches. The severity of the erosion problem has resulted in requests from the State of Hawaii for Federal assistance in the construction of a beach erosion control project at the four parks, Hauula, Punaluu, Swanzy and Kaaawa Beach Parks. Engineering studies of the erosion problem at the four parks are currently being conducted by the Corps of Engineers.

Kaneohe Bay and Mokapu Peninsula comprise the middle third section of the east shore. The northern half of the shoreline of Kaneohe Bay is primarily a rural agricultural and residential area while the southern half is a highly developed residential area. Much of the shoreline along Kaneohe Bay is artificial, the result of dredging and construction of fishponds and other structures, including open piers for recreational craft. Because this bay has a deep lagoon between an outer reef and the shore, the reef is considered by some geologists to be a barrier reef, the only example of such in Hawaii. The low wave energies within the bay preclude much reworking of materials along the shore, resulting in the creation of small deltas through deposition of sediment from streams entering the bay. The poorly sorted sediments along this shoreline are sandy gravelly silt. Mangrove has begun to grow at several locations and is



Fig. 21 Aerial view of Kaaawa Beach, Oahu

well established along the Heeia shores. Several ancient Hawaiian fishponds, some of which are being filled for residential development, line the bay.

Sandy beaches exist only along the north end of the bay. Beaches in this area are about 80 feet wide. The three beach parks along the bay are fronted by mud-flats.

Offshore, but within the bay, lie extensive shallow sand flats of irregular outline and sharp breaks in the slope of the coral reef. The lagoon bottom is mud. The main channel that enters from the north end, and much of the south end of the bay have been dredged. The barrier reef which is broad and covered with sand over much of its surface, provides effective protection against erosion of the shoreline of the bay.

Mokapu Peninsula, which is developed into a Marine Corps air station, separates Kaneohe Bay from Kailua Bay. Because the peninsula was formed by a series of volcanic eruptions, bedrock of volcanic characteristics forms much of the shoreline. The only two sandy beaches are on the north shore of the peninsula. These beaches are about 100 feet wide and are used for Marine Corps landing exercises.

The coastal reach from Kailua Bay to Makapuu Point consists of two broad bays, Kailua Bay and Waimanalo Bay, which are separated by Lanikai, a broadly convex headland. Developments in this area consist of a military air base and park, 5 public beach parks, a boat launching facility, and highly developed residential areas.

The shoreline around the points at each end of the two bays are rocky, but the shores between them consist of fair to excellent beaches. The beach fronting Kailua Bay is about 2 miles long, about 100 feet wide along the residential beach and 150 feet wide at Kailua Beach Park at the south end of the bay. The beach varies in steepness from flat at the south end to steep in the center and to moderately steep at the north end. Behind the beach are old, vegetated dunes on which beachfront residences have been constructed. The beach consists of very poorly sorted, highly calcareous sand. Critical erosion along a total of 3,000 feet of this beach has threatened beachfront residential property.

Lanikai Beach which is about 7,000 feet long and 60 feet wide fronts the headland between the two.

bays. The existence of a large but shallow offshore reef-flat and two offshore islands minimizes wave action on the beach. As a result the beach has a flat slope and the sand is poorly sorted. The northwest end of the beach has been eroding and sand from this end has deposited along the southeast end. Much of the beach is protected by structures such as seawalls and small jetties, some of which have been critically undermined by erosion.

Waimanalo beach, south of Lanikai is the longest continuous beach on Oahu. It curves gently around Waimanalo Bay for about 5 miles and ranges in width from 50 to 150 feet. The calcareous sand is medium- to fine-grained and varies from well to poorly sorted. The foreshore has a low slope and is generally cusped. Behind the beach is a series of low dunes which are covered with vegetation or by beachfront residences. Shore ownership along this long beach is divided between the military, the state, the county, and private holdings. Bellows Air Force Base fronts 12,500 feet of beach at the north end of the bay. Critical erosion has occurred along a 2,000 foot reach at the north end of the Bellows beach. The severity of the erosion has necessitated remedial action to protect beachfront property.

Except for sandy beaches at Kaupo Beach Park and

Makapuu Beach Park, the shoreline extending from Waimanalo Bay to Makapuu Point is primarily bed-rock (figure 22). The Makai Range pier facility is the only artificial structure along this reach. The beach fronting Kaupo Beach Park is about 3,300 feet long and 50 feet wide, and is composed of calcareous sand. The pocket beach at Makapuu Beach Park is about 900 feet long and 100 feet wide. It is flanked on the north by a lava point and on the south by a high sea cliff.

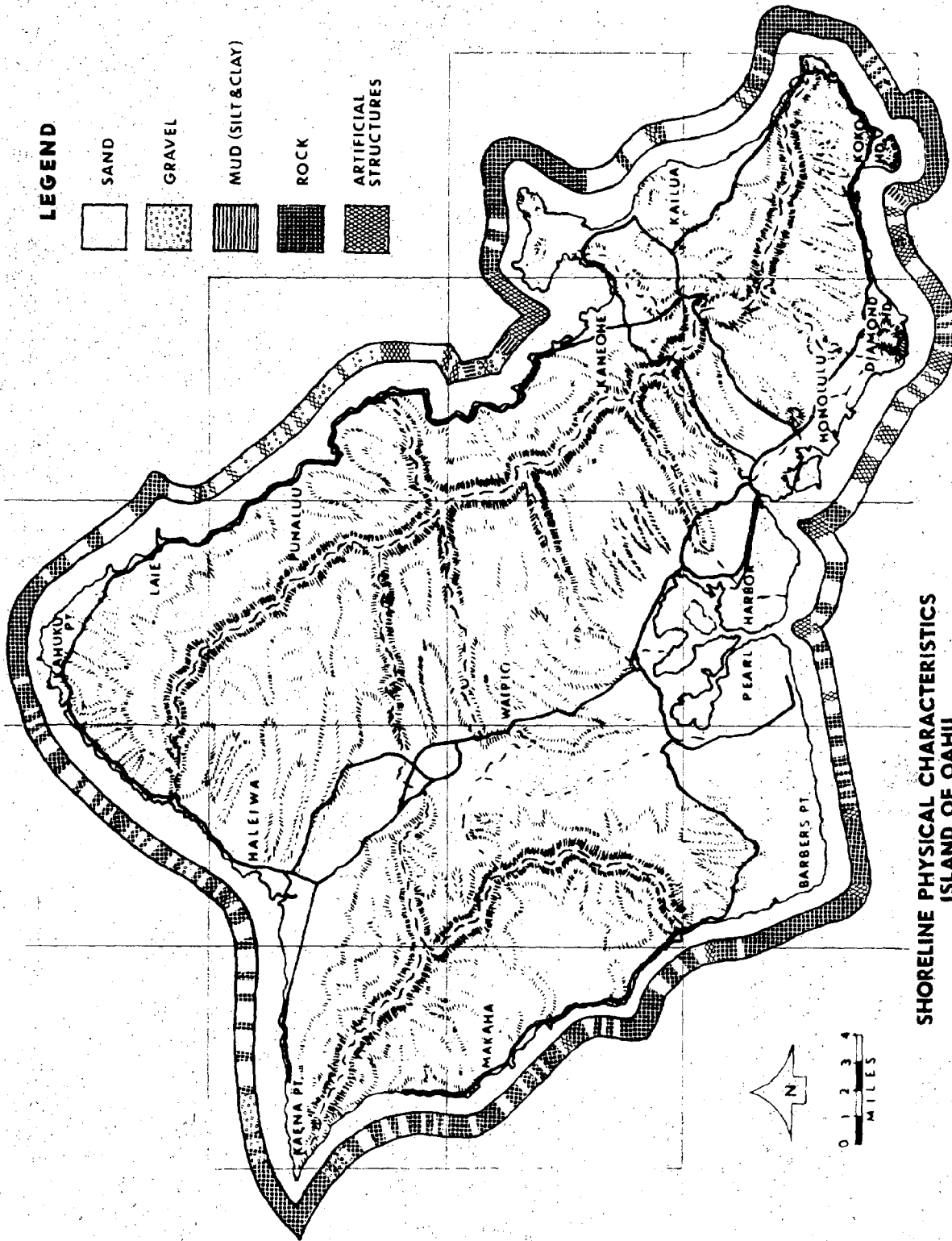
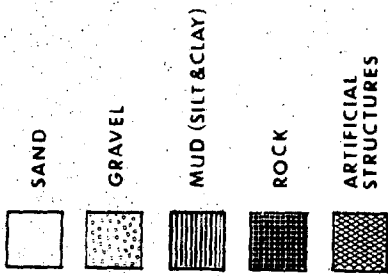
SUMMARY

Oahu is the most highly urbanized island of the State. Unlike the other major islands, approximately one-half of the shoreline of Oahu is in intensive use which includes industrial, military, resort, and residential developments. Because critical erosion of these shores could seriously affect their existing use, remedial action for these shores would have a stronger justification than that for less developed reaches. Approximately 15.2 of the 198.5 miles of shore frontage have been critically eroded; about 31.8 miles have a history of erosion but the problem is not critical at this time, and the remaining 151.5 miles have a history of stability or accretion.



Fig. 22 Aerial view of the shoreline between Kaupo Beach Park and Makapuu Point, Oahu

LEGEND



SHORELINE PHYSICAL CHARACTERISTICS
ISLAND OF OAHU

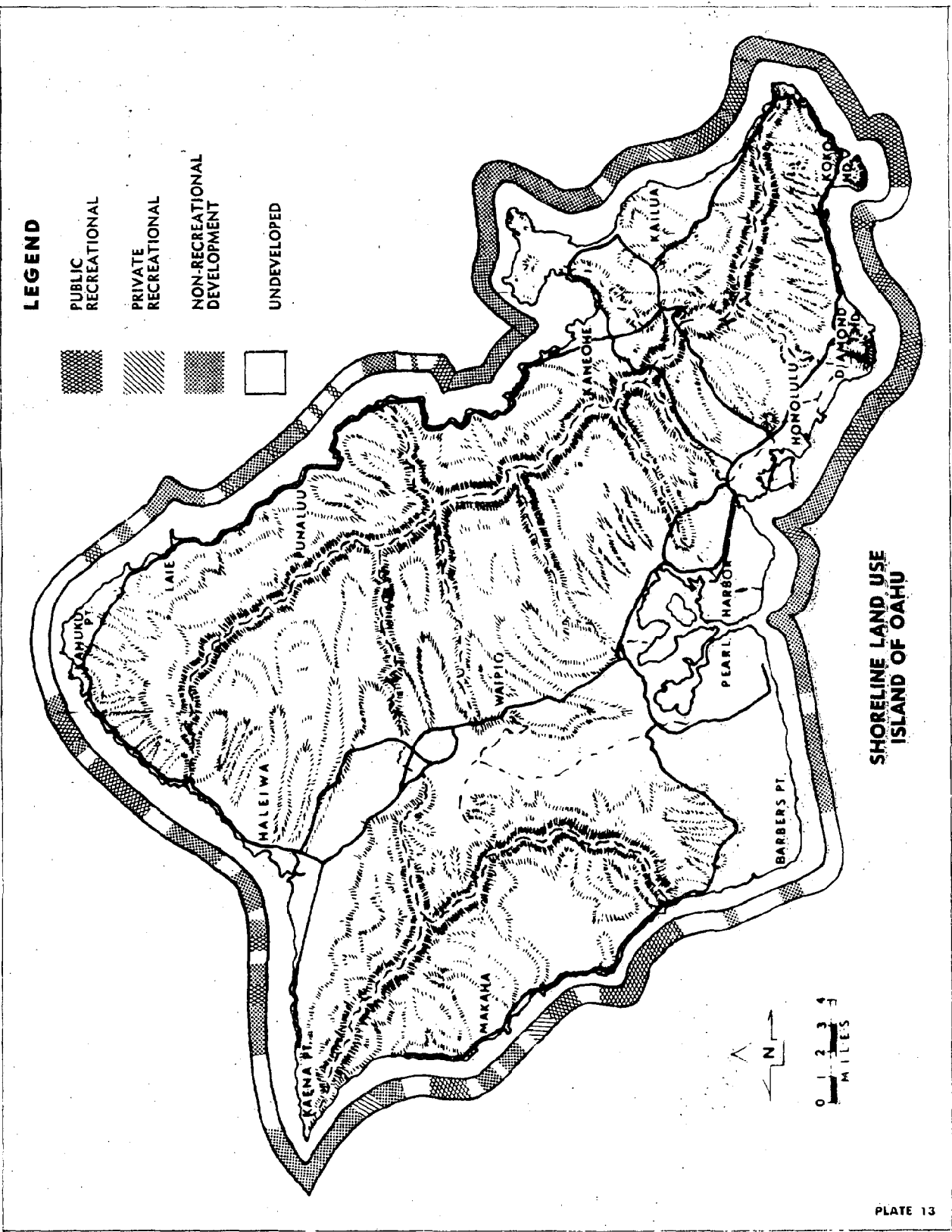


PLATE 13

LAND OWNERSHIP — 1962

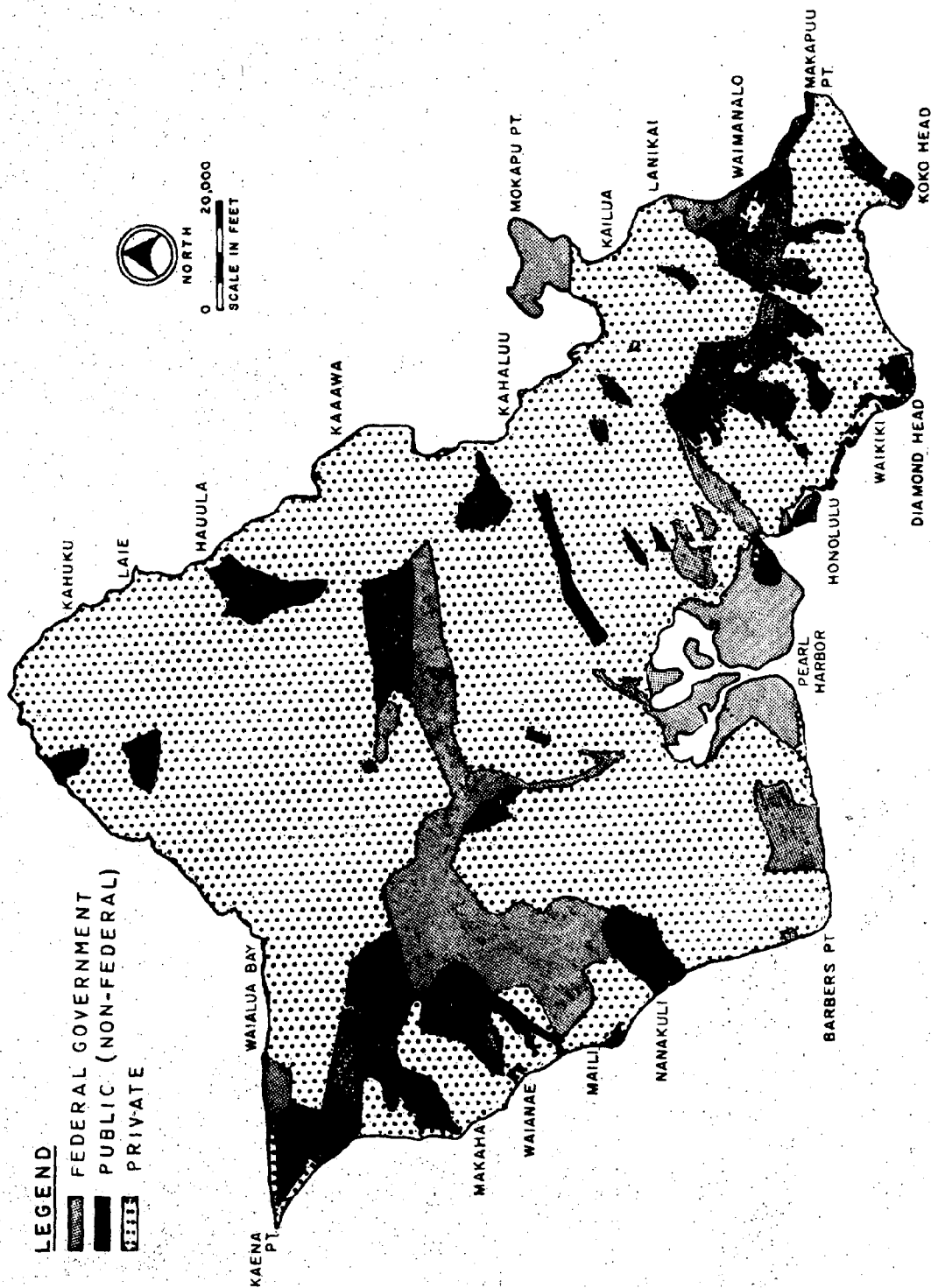
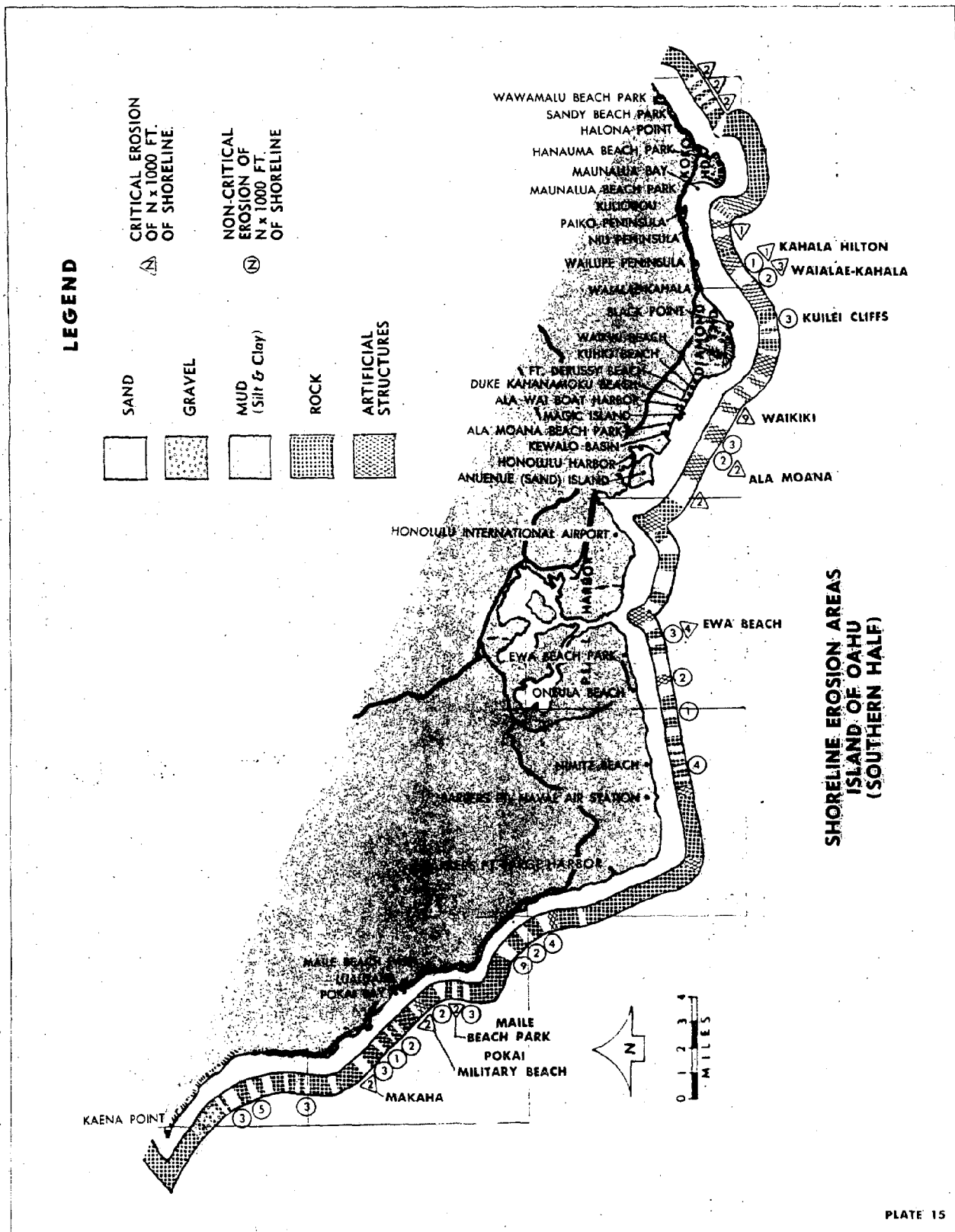


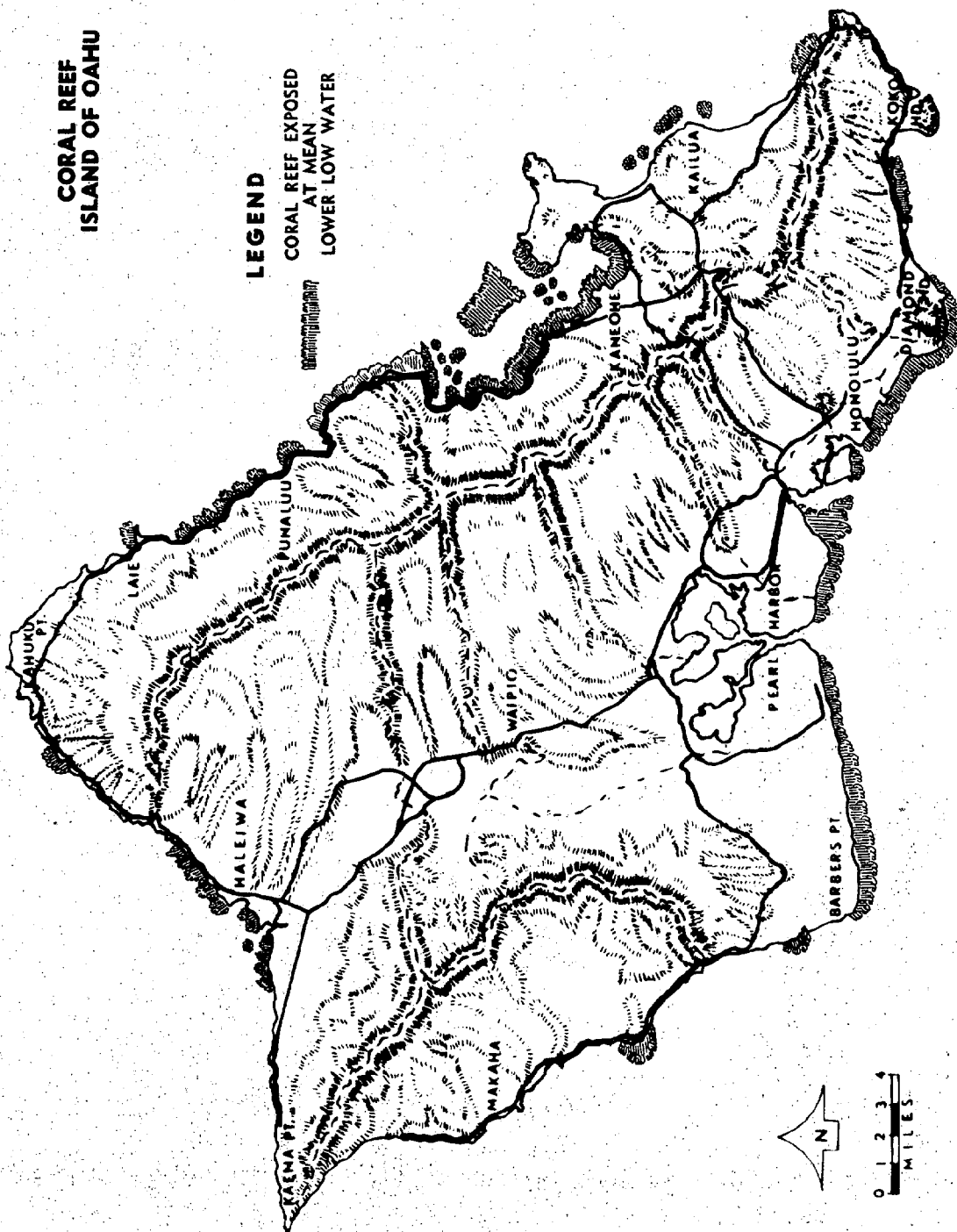
PLATE 14

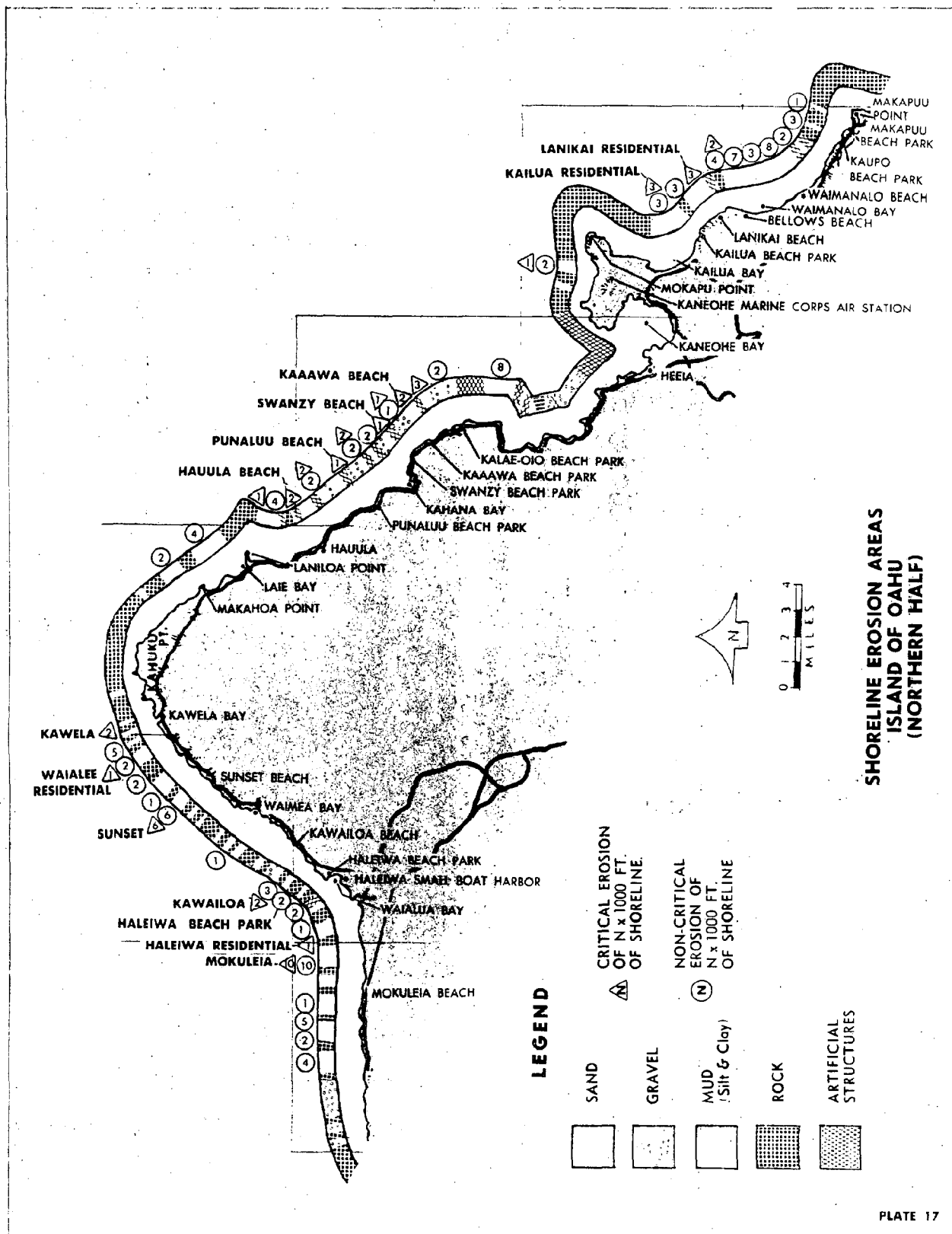


CORAL REEF ISLAND OF OAHU

LEGEND

CORAL REEF EXPOSED
AT MEAN
LOWER LOW WATER





ISLAND OF MOLOKAI

GENERAL

The island of Molokai, the fifth largest in the state, has an area of 260 square miles. It extends 38 miles due east and west and has a maximum width of 10 miles. The island was formed by the outpouring and coalescence of two volcanoes, both long extinct and now much cut and degraded by erosion.

The tidal shoreline is 105.9 miles long. About 55 percent of the shoreline is physically inaccessible or only marginally accessible by land, and includes about 14 miles of sea cliffs which are more than 1,000 feet high. The remaining 45 percent of the shoreline is physically accessible by land. Nearly half of the accessible reaches consists of sandy beaches, most of which are along the west Molokai shores. Plate 18 and table 11 summarize the characteristics of the island's shoreline.

Table 11
Shoreline Characteristics
Island of Molokai¹
(1962)

Characteristics	Statute Miles	Percent
Rock	53.0	50.1
Gravel	13.7	12.9
Sand	24.6*	23.2
Mud (Silt and Clay)	7.1	6.7
Artificial structures	7.5	7.1
Total	105.9	100.0

¹Offshore islands excluded.

*Includes 1.4 miles of seasonal sand beaches where the predominant beach material is sand for only a part of the year.

Source: "Hawaii's Shoreline" prepared by the State of Hawaii Department of Planning and Economic Development in 1965.

SHORELINE USE

Shoreline use in 1962 is shown on plate 19 and summarized in table 12 which shows that 97.2 miles or 91.7 percent of Molokai's shoreline is undeveloped. Most of the shoreline developments are along the south shore. The north shore is essentially undeveloped primarily because of extremely difficult accessibility. The economy of the island, which is presently centered around pineapple cultivation and cattle grazing, is expected to remain fairly static. Although the tourist industry is presently an insignificant factor in the island's economy, the west coast with its fine climate and beaches has a recognized potential for resort development. However, such development is not expected to be as rapid and extensive as on some of the other major islands of the state.

Table 12
Shoreline Land Use
Island of Molokai¹
(1962)

Land Use	Total Shoreline		Sandy Beach	
	Miles	% of Total	Miles	% of Total
Recreational—Public	0.9	0.9	0.8	3.4
Recreational—Private	0.0	0.0	0.0	0.0
Non-Recreational Development	7.8	7.4	3.3	14.3
Undeveloped	97.2	91.7	19.1	82.3
Total	105.9	100.0	23.2	100.0

¹Offshore islands excluded.

Source: "Hawaii's Shoreline" prepared by the State of Hawaii Department of Planning and Economic Development in 1965.

SHORELINE OWNERSHIP

Table 13 and plate 20, the latest data on shoreline ownership, shows that most of the island's shoreline and sandy beaches are privately owned. The land ownership reflected in the table is expected to remain relatively static.

Table 13
Shoreline Land Ownership
Island of Molokai¹
(1962)

Owner	Total Shoreline		Sandy Beach	
	Miles	% of Total	Miles	% of Total
Federal	2.2	2.1	0.0	0.0
Public (non-Federal)	16.5	15.6	3.2	13.8
Private	87.2	82.3	20.0	86.2
Total	105.9	100.0	23.2	100.0

¹Offshore islands excluded.

Source: "Hawaii's Shoreline" prepared by the State of Hawaii Department of Planning and Economic Development in 1965.

PHYSICAL CHARACTERISTICS AND HISTORY OF SHORELINE

Table 14 describes the physical characteristics, ownership, use and condition of the principal sandy beaches of Molokai. The following discussion supplements the data in the table by providing general descriptions of the physical characteristics of the

Table 14
Characteristics of Principal Beaches on Molokai

Name	Stability Classification Length in 1,000 Feet			Length Feet	Width Feet	Type of Beach		Predominant Beach Composition	Shore Ownership			Shore Use in Linear Feet			
	Critical Erosion	Non-Critical Erosion	Non-Eroding			Natural	Artificial		Public	Non-Federal	Private	Recreational		Non- Recreational	Undeveloped
												Public	Private		
Southwest Shore															
Holena	5	10		15,000	100	X		Calcareous			X			15,000	
Kanalukaha		10		10,000	100	X		"		X				10,000	
Northwest Shore															
Papohaku		12		12,000	300	X		Calcareous			X		2,000	10,000	
Kepuhi			1	1,000	100	X		"			X			1,000	
Kawaaloa		2		1,500	225	X		"		X		1,500			
Moomomi			1	600	100	X		"			X			600	
North-Central Shore															
Kalaupapa		3		3,000	75	X		Volcanic		X				3,000	
Kalaemilo		3		3,000	75	X		Calcareous		X			3,000		
Northeast Shore															
Halawa Bay		—		300	40	X		Volcanic			X			300	
Southeast Shore															
Pohakuloa to Pukoo Beaches, (5 miles coastal reach, 3 miles of beaches)	8	8		16,000	20	X		Calcareous		X	X		2,000	11,000	

1,000 Ft. Public, 15,000 Ft. Private.

shoreline of Molokai, and general assessments of shoreline condition. For this discussion, the island was divided into 6 sections.

Southeast Shore (plate 21). This reach extends from Cape Halawa to Kamalo Harbor. Numerous small rural communities are scattered along the southern two-thirds of this reach. The northern third remains undeveloped and is characterized by low sea cliffs, a few small pocket beaches, and minor reef development.

The shoreline from Cape Halawa to Kanaha Beach is a physically inaccessible reach of sea cliffs. The cliffs are about 100 feet high at Cape Halawa, but generally less than 50 feet high to the southwest. Kanaha Beach at the west end of the reach of sea cliffs is a small arcuate pocket beach about 65 feet wide and 175 feet long. It is characterized by a moderately steep foreslope and is composed of well sorted, coarse grains of calcareous limestone. The backshore is marked by vegetation, and in some places by a 3-foot-high escarpment cut into alluvial fill.

The shoreline extending from Pohakuloa to Kamalo Harbor is predominantly artificial. Most of the 53 ancient Hawaiian fishponds on the coast of Molokai are on the reef flat within this reach. Most of the fishpond walls are in a badly deteriorated condition, and the ponds are silting rapidly.

A narrow coastal plain built by the deltas of intermittent streams extend along this coast. There are several reaches of sandy beaches between fishponds and mudflats, but most of them are very narrow. Pebble beaches are common at the small deltas fronting stream mouths.

A shallow fringing reef which is often more than a mile wide extends along the southern two-thirds of the southeast shore. There are natural deep indenta-

tions every mile or so along the eastern part of the reef. Considerable red silt is being deposited on the reef surface, but large patches of sandy bottom are also present.

South-Central Shore (plate 21). This reach extends from about one-fourth mile west of Kamalo Harbor to about a half mile west of Ooia Fishpond, and is the most highly developed reach of the island. Kaunakakai, the principal city and population center of Molokai, lies within this reach.

The shoreline from Kamalo Harbor to Kaunakakai is characterized by alternating stretches of sand, gravel, and artificial structures, primarily ancient Hawaiian fishponds. Although the sandy beaches are of considerable length, most of them are only a few feet wide. Gravel beaches are most common at the small deltas at the mouths of intermittent streams which drain the broadly convex slopes of east Molokai. Most of the fishponds are in a badly deteriorated condition, and the ponds are silting rapidly. A shallow fringing reef which is more than a mile wide in places, extends along the Kaunakakai end of this reach (plate 22).

The shoreline fronting the town of Kaunakakai was altered by construction of a barge harbor in 1934. This harbor, the principal port for the island, consists of a dredged channel and barge basin 1,500 feet long, 600 feet wide, and 23 feet deep, and a 2,700-foot-long paved mole with a wharf facility at the seaward end (figure 23).

The shoreline west of Kaunakakai consists of growths of mangrove over tidal mudflats.

Southwest Shore (plate 21). Except for a barge harbor and a Coast Guard reservation, the reach from Ooia Fishpond to Kaheu Gulch is undeveloped. Mudflats comprise the west end up to Pakanaka Fishpond.

The shoreline from the fishpond to Kolo Wharf consists of narrow beaches, some of which are primarily sandy while others, particularly those near stream mouths, are cobble beaches. Small lengths of mixed cobble and sand beaches, old fishpond walls, and mangrove also exist within this reach. The edge of the fringing reef in this area is about a mile offshore. The reef is being rapidly covered by red silt washed down from cultivated and grazed fields.



Fig. 23 Aerial view of Kaunakakai Barge Harbor, Molokai

Kolo Wharf is a 600-foot-long abandoned pier and wharf facility approximately 3.5 miles east of the Hale O Lono Barge Harbor. The shoreline between the two facilities is a mixed cobble and sand beach with an average width of 100 feet. It is generally sandier at both ends than in the middle.

The Hale O Lono Barge Harbor consists of a 1,500-foot-long east breakwater and a 1,100-foot-long west breakwater, an 18-foot deep and 500-foot-square turning basin, and a 260-foot-long wharf. This privately operated facility was constructed in 1959.

The shoreline from Hale O Lono to Laau Point consists of alternating stretches of beachrock and sandy beaches. Kanalukaha, one of the sandy beaches within this reach, is 10,000 feet long, 100 feet wide, and primarily composed of calcareous sand. At one time this beach had large deep cusps with beachrock exposed in troughs except at the western end which had a high berm with a moderately steep foreslope. The sand consisted of extremely well sorted coarse grains of calcareous material. However, in early 1962, sand mining operations were initiated and by spring of that year the beach was completely destroyed. Although much of the beach has returned since termination of sand mining, jagged beachrock are still exposed in some places.

The shoreline around Laau Point to Kaheu Gulch consists of lava basalt sea cliffs and lengthy stretches

of beachrock. Storm beaches, large areas of sand deposited inland of the beachrock by storm waves, are common along this reach. Kamakaipo, the largest of these beaches, is about one mile long. The sand is well sorted, very coarse, extremely low in volcanic material and about two feet thick along the foreshore. Low vegetated dunes exist along the backshore.

Kaunalu Beach is a small pocket beach at the head of Kaunalu Bay north of Kaheu Gulch. Both ends of this 60-foot-wide, 150-foot-long beach terminate against boulders lying against basaltic rock which form the points of the bay. The sand consists of well sorted, very coarse grains of predominantly calcareous material.

A small unnamed pocket beach lies at the head of a small bay about a half-mile north of Kaunalu Bay. The beach partly bars an unnamed intermittent stream and is about 80 feet wide and 250 feet long. A berm exists only where the stream meets the beach. The foreshore along the rest of the beach extends inland with a steady rise to a grassy, flat backshore area. The sand is poorly sorted and contains a small amount of volcanic material among the predominantly calcareous grains.

Northwest Shore (plate 23). A Coast Guard reservation at Ilio Point and a small sand-mining facility are the only developments along the northwest shore which extends from Kaunalu Bay to about 3 miles east of Kawaaloa Bay. Pocket beaches at the head of tiny inlets interrupt the low sea cliff from Kaunalu Bay to Puu Koa south of Papohaku Beach.

One of the finest in the state, Papohaku Beach lies between a lava headland at the south end and a cinder cone headland on the north. This fairly straight beach is 12,000 feet long, 300 feet wide, and consists of well sorted, coarse, medium grains of predominantly calcareous material (figure 24). The sand extends offshore for about 1,200 feet. A private construction company maintains a permanent sand-mining operation at the southern end of the beach. The year-round removal of sand is dependent on littoral drift in a southerly direction. However, due to a combination of excessive sand removal and to a winter of successive southern storms which produced a northward littoral drift during 1962 and 1963, critical erosion at the southern end of the beach washed out the quarrying operation. Since that time, the sand-mining facility has resumed operation.

The cinder cone at the north end of Papohaku Beach separates it from the 1,000-foot-long, 100-foot-wide beach at Kepuhi. This slightly arcuate beach is composed of well sorted, medium grains of calcareous sand. A steep foreslope reflects the occurrence of plunging breakers along this beach.

The shoreline from Kepuhi Beach to Ilio Point consists of alternating reaches of sand and gravel beaches as well as low sea cliffs. These cliffs gradual-

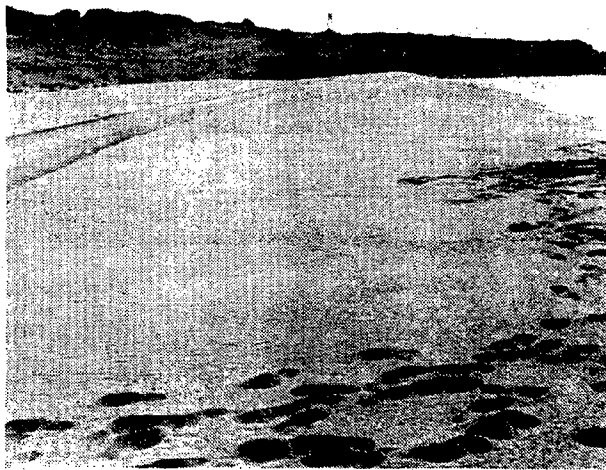


Fig. 24 Papohaku Beach, Molokai

ly increase in height and are from 100 to 500 feet high along the physically inaccessible reach between Ilio Point and Kapalauoa.

The reach between Kapalauoa and Moomomi Beach has one of the most impressive dune developments in Hawaii. Between Kapalauoa and Kalani Beach, the dunes extend 4.5 miles inland and are fed by three calcareous beaches (Kalani, Kawaaloo and Moomomi) to the north. The shoreline fronting Kalani Beach consists of beachrock at the waterline, behind which lies a 100-foot-wide storm beach.

Kawaaloo Beach which has a length of 1,500 feet and an average width of 225 feet, is subject to seasonal accretion and erosion. The sand is well sorted, coarse in size, and predominantly composed of calcareous grains. The foreshore is moderately steep and is typically scalloped by large cusps. The backshore is a series of sand dunes built by the brisk trade-winds which sweep almost continuously across this beach. Older dunes, some of which have solidified, extend across the island and are known as the Molokai "Desert Strip." A coral reef lies about 250 feet offshore.

Moomomi Beach is a 600-foot-long, 100-foot-wide pocket beach which is separated from Kawaaloo Beach on the west by a rocky headland. Sand along this beach is predominantly calcareous. Large patches of sand also exist offshore.

North-Central Shore (plate 23). Except for a Coast Guard reservation and urban development at Kalaupapa, the shoreline along this reach which extends

from about three miles east of Kawaaloo Bay to Kalaupapa Peninsula is undeveloped. Sea cliffs which are less than 50 feet high near Moomomi Beach extend to the west end of the Kalaupapa Peninsula where they rise to about 1,700 feet.

The only three sandy beaches within the north-central shore lie along the west side of Kalaupapa Peninsula. Data are available on only two of these beaches. Kalaupapa Beach, the southernmost beach, is about 3,000 feet long and 75 feet wide. The west end of the beach terminates against a talus of boulders at the base of 1,600-foot-high sea cliffs, and the east end terminates against low outcrops of lava. The beach is subject to seasonal accretion and erosion. Beach sand consists of a well-sorted mixture of medium-sized grains which are largely volcanic in origin and therefore black in color. The backshore of the beach ends abruptly against a boulder talus at the base of high cliffs. There is no offshore reef; instead a sandy bottom with a steep slope extends off the beach.

Except for the Kalaupapa Barge Harbor, the coast between Kalaupapa Beach and Kalaemilo Beach to the north consists of low outcrops of lava basalt. The barge harbor was improved by the Corps of Engineers in 1967, and presently consists of a 114-foot rubble-mound breakwater and a 0.6-acre entrance channel and basin area.

The 3,000-foot-long, 75-foot-wide Kalaemilo Beach immediately north of the urban development at Kalaupapa is subject to seasonal accretion and erosion. As such, the shoreline is sometimes marked by exposures of lava and beachrock. In contrast to Kalaupapa Beach, this beach is composed of predominantly calcareous sand which is very well sorted and medium-grained in size. A rocky bottom with numerous sand pockets extends offshore.

Except for storm beaches and patches of blown sand, the shoreline along the north and east sides of Kalaupapa Peninsula consists of sea cliffs which rise to about 100 feet at the southeast corner.

Northeast Shore (plate 23). The shoreline from Kalaupapa Peninsula to Cape Halawa is one of the most spectacular reaches of Hawaii's shoreline. This reach consists of sea cliffs which are more than 3,000 feet high in the central section and about 100 feet high at both ends (figures 25 and 26). It is interrupted by large valleys at Waileia, Waikolu, Pelekunu, Wailau, Papalaua, and Halawa, all of which have alluviated bottoms and some of which have beaches at the valley mouths.

The shoreline fronting Pelekuni and Wailau Valleys has a cobble-beach base which is covered by sand during the summer months. At Halawa Bay, a low sea cliff divides the shoreline into two arcuate pocket beaches, both of which are backed by sand dunes. The beach at the northwest end of the bay consists



Fig. 25 Sea stack and steep seacliffs along the northeast coast of Molokai

of cobbles and boulders which are seasonally covered by sand. The beach at the southeast end consists of well sorted, medium grains of volcanic fragments and calcareous material in about equal proportions. Offshore, the bottom is rocky and covered with boulders out to about the 25-foot-depth. Several sea stacks, which are parts of old sea cliffs isolated by marine erosion, exist offshore. Some of them are more than 350 feet high.

SUMMARY

About 2.5 miles of the shoreline of the island of Molokai are considered to be undergoing critical erosion. About 9.1 of the 105.9 miles of shoreline have a history of erosion but the problem is not critical at this time. The remaining 94.3 miles have a history of stability or accretion.

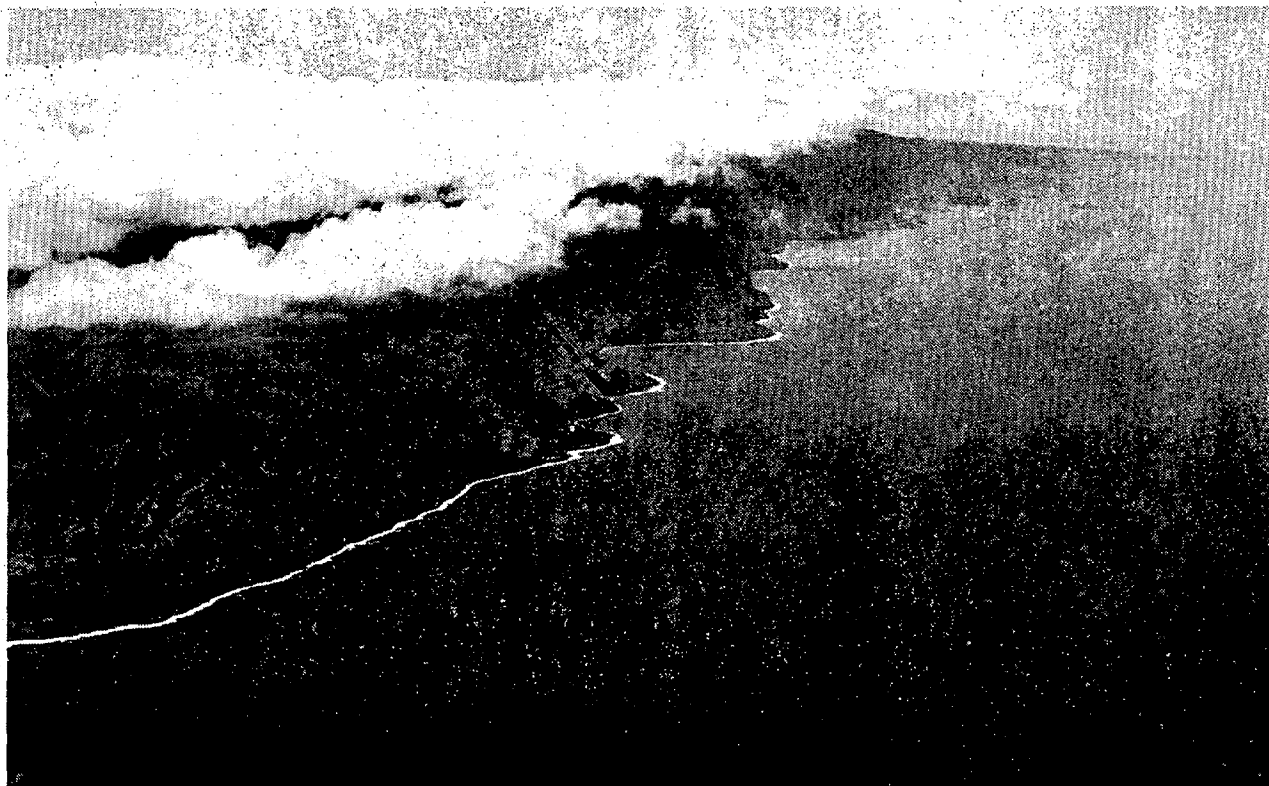
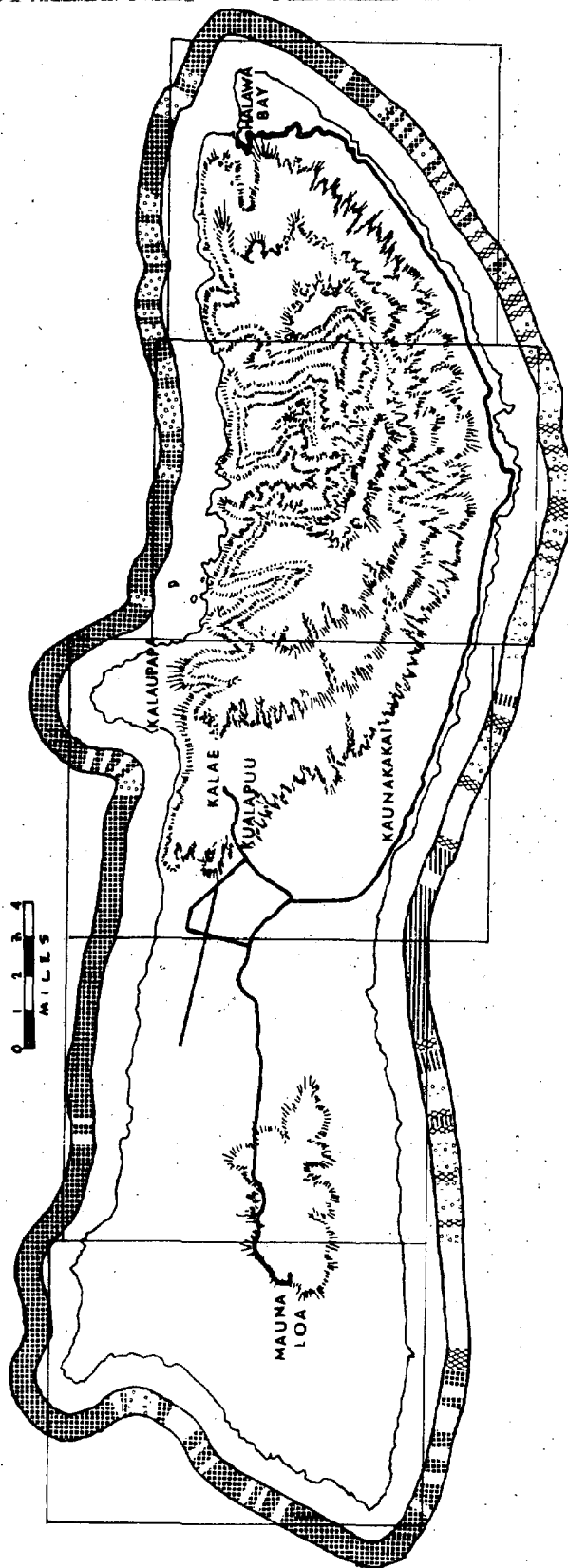
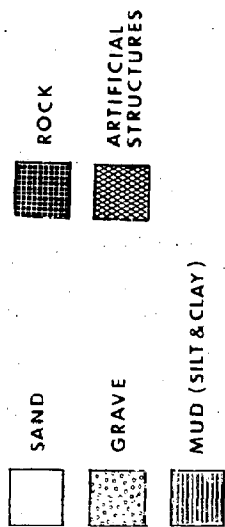






Fig. 26 Aerial view of seacliffs along northeast coast of Molokai (Camera Hawaii Photo)

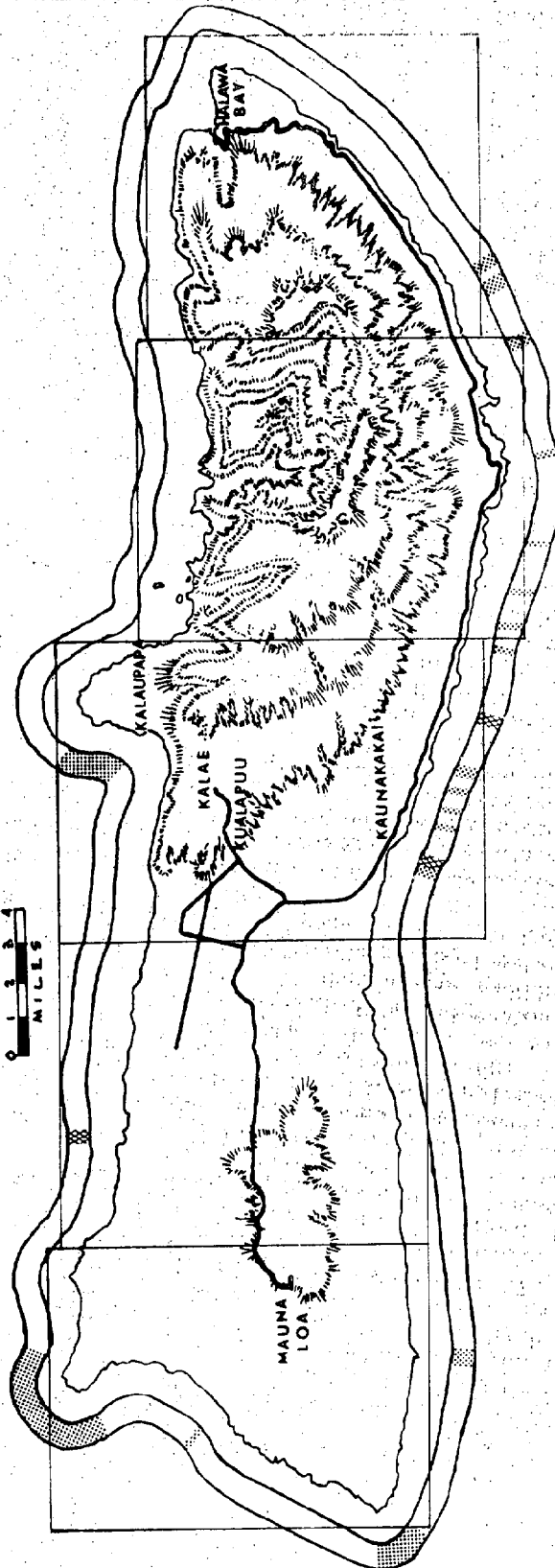
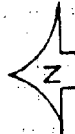
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SHORELINE PHYSICAL CHARACTERISTICS
ISLAND OF MOLOKAI

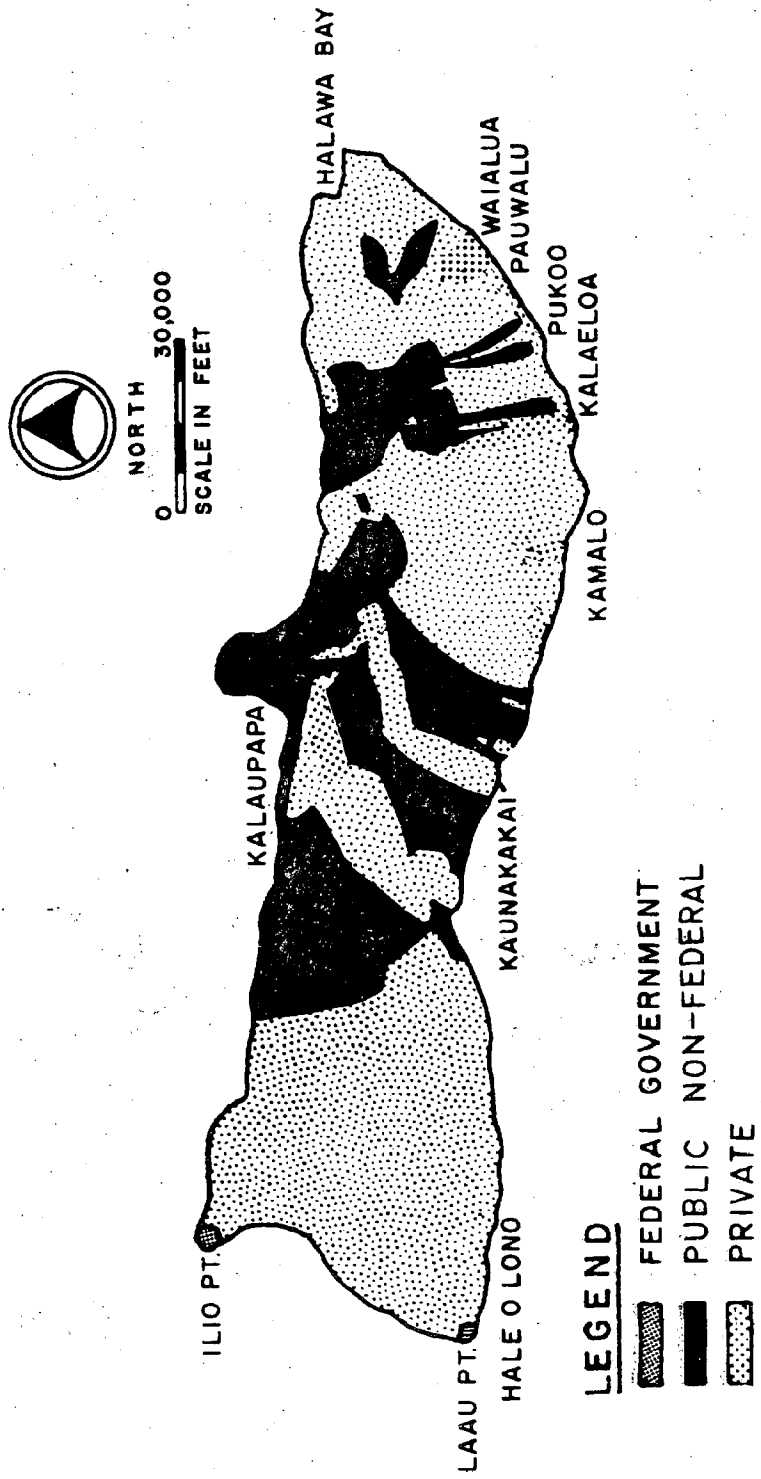
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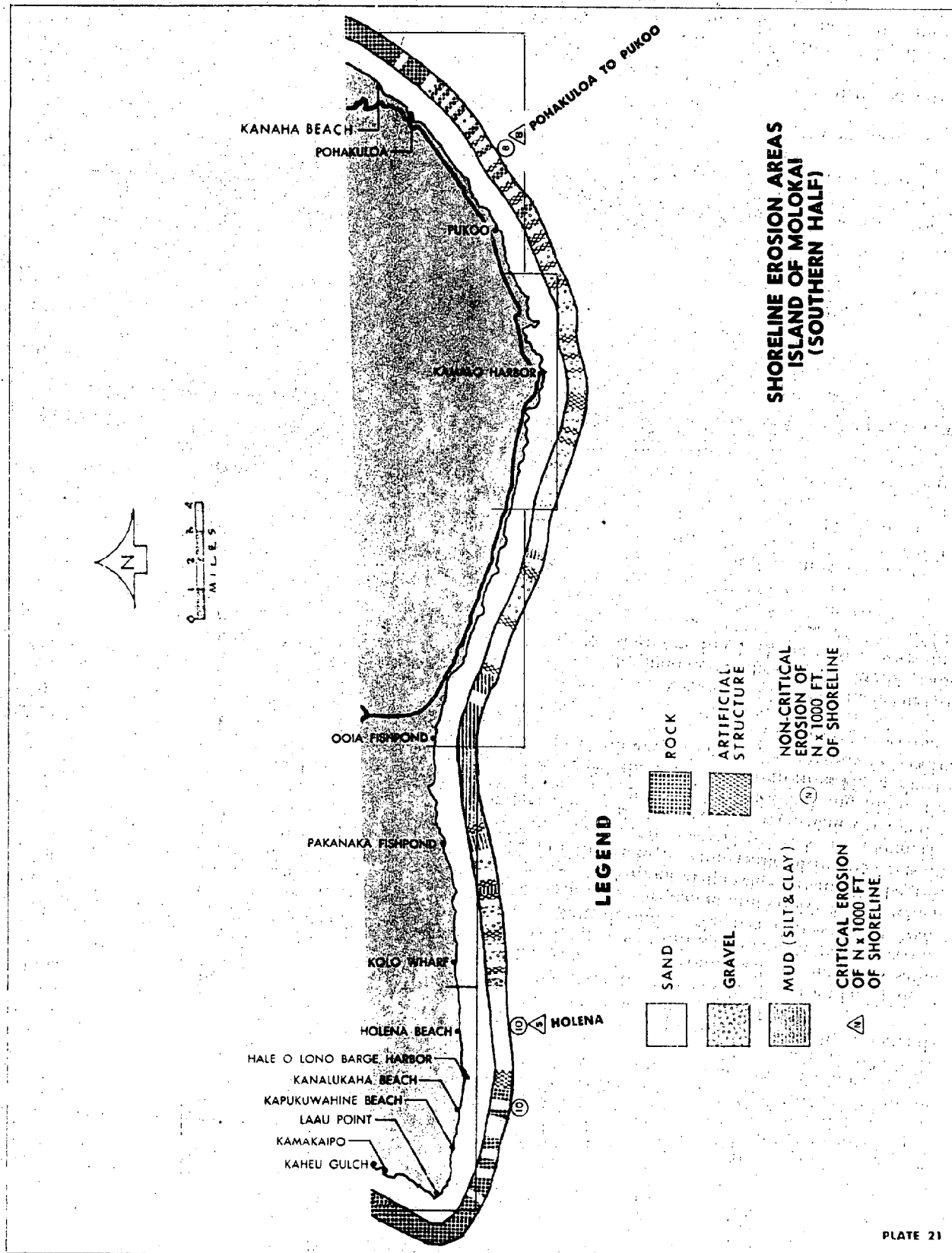
-  PUBLIC RECREATIONAL
-  PRIVATE RECREATIONAL
-  NON-RECREATIONAL DEVELOPMENT
-  UNDEVELOPED



**SHORELINE LAND USE
ISLAND OF MOLOKAI**

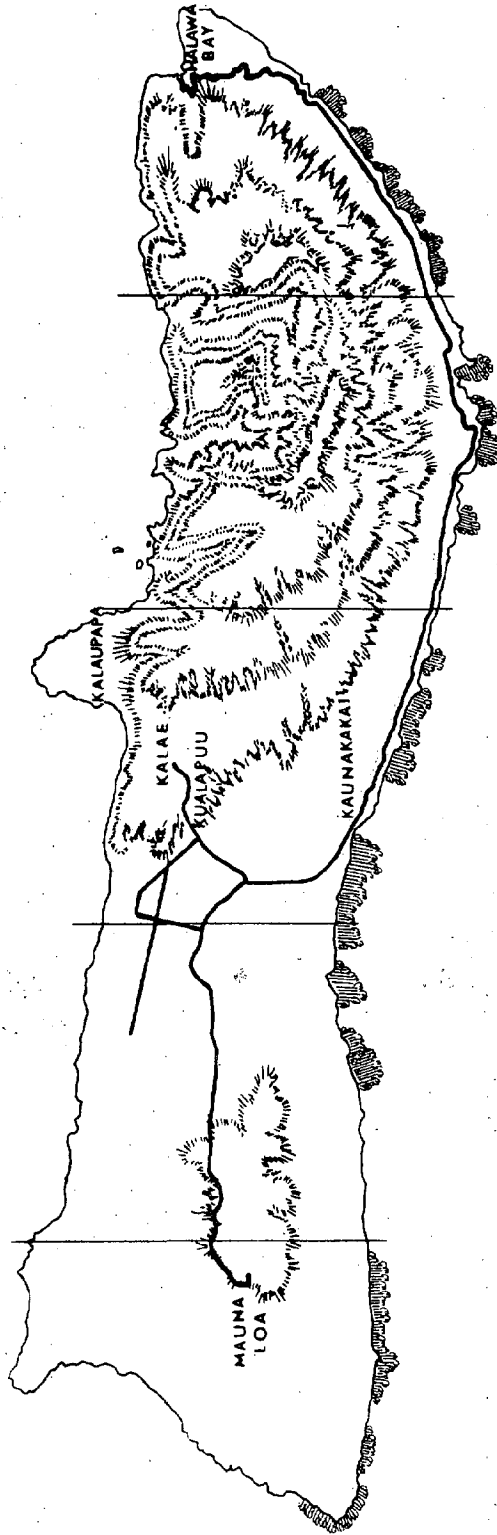
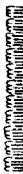
LAND OWNERSHIP — 1962





LEGEND

CORAL REEF EXPOSED
AT MEAN
LOWER LOW WATER



CORAL REEF ISLAND OF MOLOKAI

ISLAND OF LANAI

GENERAL

The island of Lanai, an extinct shield-type volcano, has an area of 141 square miles. Most of the island is a high plateau with a maximum elevation of 3,370 feet above sea level. Lanai City, the only town on the island, is located on the plateau at an elevation of 1,620 feet.

The tidal shoreline is only 52.3 miles long, half of which is rocky and physically inaccessible by land. A little less than half is accessible, of which nearly three-fourths is sandy beach. The characteristics of the island's shoreline are summarized in table 15 and shown on plate 24.

Table 15
Shoreline Characteristics
Island of Lanai¹
(1962)

Characteristics	Statute Miles	Percent
Rock	30.4	58.1
Gravel	3.6	6.9
Sand	18.2	34.8
Mud (Silt and Clay)	0.0	0.0
Artificial structures	0.1	0.2
Total	52.3	100.0

¹Offshore islands excluded.

Source: "Hawaii's Shoreline," prepared by the State of Hawaii Department of Planning and Economic Development in 1965.

SHORELINE USE

Shoreline use in 1962 is summarized in table 16. Plate 25 shows that except for recreational development at Manele Bay and a barge harbor at Kaunapali, the island's shoreline is undeveloped.

No dynamic changes in development of the island's shoreline are anticipated. Lanai's already small popu-

lation is expected to continue to decline due to out-migration. Unlike the island of Kauai, no reversal of Lanai's economic decline is foreseen in the near future since no new developments such as resort hotels and tourist destination centers have been planned for this island. The economy of the island would probably remain centered around pineapple cultivation.

Table 16
Shoreline Land Use
Island of Lanai¹
(1962)

Use	Total Shoreline		Sandy Beach	
	Miles	% of Total	Miles	% of Total
Recreational—Public	0.7	1.3	0.6	3.3
Recreational—Private	0.0	0.0	0.0	0.0
Non-Recreational				
Development	0.8	1.5	0.1	0.5
Undeveloped	50.8	97.2	17.5	96.2
Total	52.3	100.0	18.2	100.0

¹Offshore islands excluded.

Source: "Hawaii's Shoreline," prepared by the State of Hawaii Department of Planning and Economic Development in 1965.

SHORELINE OWNERSHIP

Almost all of the island of Lanai is owned by one large landholder who also owns 98.5 percent of the shoreline, including the 18.2 miles of sandy beaches (plate 26). About 1 percent (0.5 mile) of the shoreline is owned by the Federal Government and consists of light stations operated by the U.S. Coast Guard. The remaining 0.5 percent of the shoreline is owned by the State of Hawaii.

Table 17
Characteristics of Principal Beaches on Lanai

Name	Stability Classification Length in 1,000 Feet			Length Feet	Width Feet	Natural Beach	Predom. Beach Compo- sition	Private Owned Shore	Private Recrea- tional Use	
	Critical Erosion	Non-Critical Erosion	Non-Eroding						Lin. Ft.	Undeveloped Lin. Ft.
Hilopoe Bay Beach		2		1,500	100	X	Calcareous	X	1,500	
Pohihua	1	5		9,000	150	X	Calcareous	X		9,000
Hauola		5		5,000	35	X	Volcanic	X		5,000

PHYSICAL CHARACTERISTICS AND HISTORY OF SHORELINE

Table 17 describes the physical characteristics, ownership, use, and condition of the principal sandy beaches of Lanai. The following discussion supplements the data in the table by providing general descriptions of the physical characteristics of the shoreline and general assessments of shoreline conditions. For this discussion, the island was divided into two sections.

West Shore. The reach extending from Kamaiki Point to Polihua Beach is primarily sea cliffs. Sandy beaches occur only at the head of Manele and Hulopoe Bays and along the northwest end of this reach. Three developed shoreline areas of the island are located along this shore.

A sea cliff which extends southwestward from a point near Kapoho Gulch is low for the first mile,

but becomes gradually higher along the coast to Manele Bay. Prior to 1965, a small pocket beach existed at the head of Manele Bay, which is bound by steep faults on the east and by a lava terrace on the west. The northeast end of the beach consisted of coral sand and was separated from a larger beach to the southwest by a short reach of rocky shore. The larger beach was nourished by dark basalt sediment, and was therefore referred to as Black Manele Beach.

This beach was modified in 1965 by construction of a small boat harbor. Artificial structures comprising the harbor include a 470-foot-long rubblemound breakwater extending from the east side of the bay, a launching ramp, and 12 finger piers (figure 27).

Manele Cone, a cinder and spatter cone which has been extensively shaped by marine action, separates Manele Bay from Hulopoe Bay. A small pocket beach

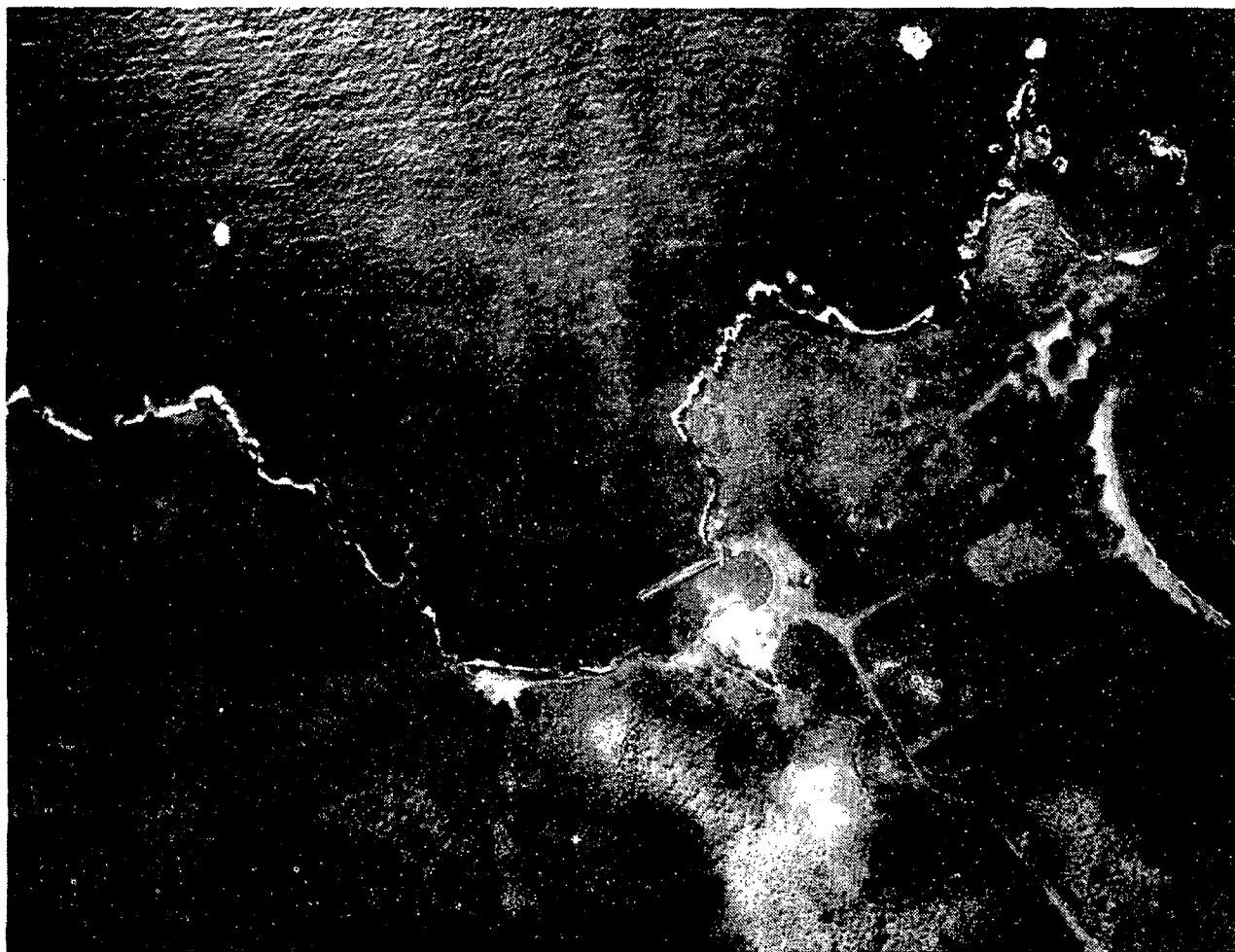


Fig. 27 Aerial view of Manele Harbor, Lanai

lies at the head of a cove formed by the east side of the cone which is a sea cliff and the west side which is a bench about five feet above sea level. The cone is now a peninsula which is tied to the main island by beach sediments that are still being deposited in Manele and Hulopoe Bays.

A 1,500-foot-long, 100-foot-wide arcuate pocket beach lies at the head of Hulopoe Bay. Boulders lying against lava points occur at each end of the beach, which is composed of a mixture of medium and coarse grains of calcareous material. Low dunes and a beach park occupy the backshore. The foreslope is steep, a result of the large swells which attack the beach which is subject to seasonal accretion and erosion.

The shoreline from Hulopoe Bay to Palaoa Point is generally a low sea cliff. The Kaholo Pali, which extends from Palaoa Point to Kaumalapau Harbor, rises to 1,000 feet in elevation just north of Palaoa Point, and is the highest sea cliff on Lanai.

Kaumalapau Harbor, which essentially consists of a 400-foot-long barge wharf and a 250-foot-long breakwater, is privately owned. The harbor was constructed for exclusive use by barges, however, prior to construction of the Manele Small Boat Harbor, it accommodated fishing vessels and other small craft. The harbor is the island's only interisland shipping terminal.

Polihua Beach lies along the northwesternmost part of Lanai and is an excellent beach with large quantities of sand. It is about 9,000 feet long, with an average width of 150 feet. The beach is subject to seasonal changes. During the late fall, sand shifts to the eastern end of the beach, and by winter the eastern portion is built out to widths of over 350 feet. The reverse situation occurs during the summer when sand shifts westward. The sand is moderately well sorted, medium and coarse in grain size, and contains very little volcanic detritus. A low sea cliff occupies the backshore at the west end of the beach, whereas large, high dunes lie back of the beach at the east end. The entire reach usually has a moderately steep foreshore, a result of large waves which frequently strike this beach. In addition to large waves, an extremely strong alongshore current sweeps westward along this beach.

East Shore. Except for a small industrial development at Kaiolohia Bay, this reach is undeveloped. The shoreline extending from Polihua Beach to Kahokunui at the delta of a gulch consists of alternating stretches of beach and beachrock, with dune areas behind the beaches and mud and gravel at stream mouths.

From Kahokunui to Halepalaoa Landing, the shoreline consists of narrow beaches of fine sand chiefly of detrital origin. Small deltas of pebbles and cobbles exist near stream mouths. Such a delta exists at Hauola Gulch where a continuous alluvial flat has been built out during historical time. A 5,000-foot-long,

35-foot-wide beach fronting the delta consists of gravel and moderately sorted, medium-sized sand composed almost entirely of olivine and lava fragments. The backshore is a poorly sorted mixture of mud and gravel which is intermittently washed seaward by Hauola Stream. The beach is relatively stable because of a protective reef which extends about 1,300 feet offshore (plate 27).








Beaches along the reach extending from Halepalaoa to Makaiwa Point are composed of calcareous sand. However, beaches south of Makaiwa Point become coarser grained, and as the reef narrows past Naha the shore becomes a pebble and cobble beach which continues past Kapoho delta where a sea cliff begins.

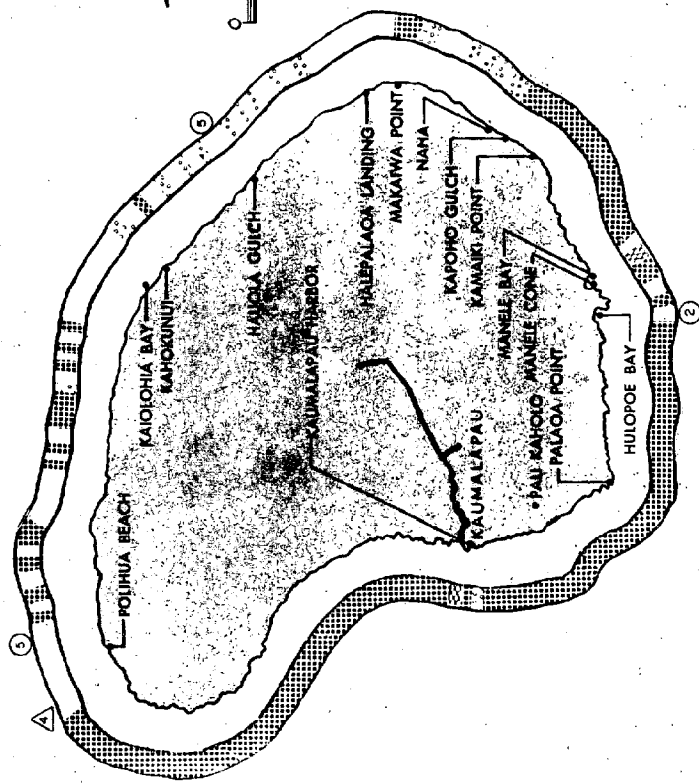
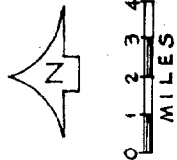
One of the longest stretches of fringing reefs in the state lies off the northeast coast of Lanai. In several places, the reef is more than 3,000 feet wide. Together with the island of Molokai and Maui, the reef protects the northeast shore from storm waves so that beaches along this shore are relatively stable.

SUMMARY

About 0.8 mile of the shoreline of the island of Lanai is undergoing critical erosion. About 2.3 of the 52.3 miles of shoreline have a history of erosion but the problem is not critical at this time. The remaining 49.2 miles have a history of stability or accretion.

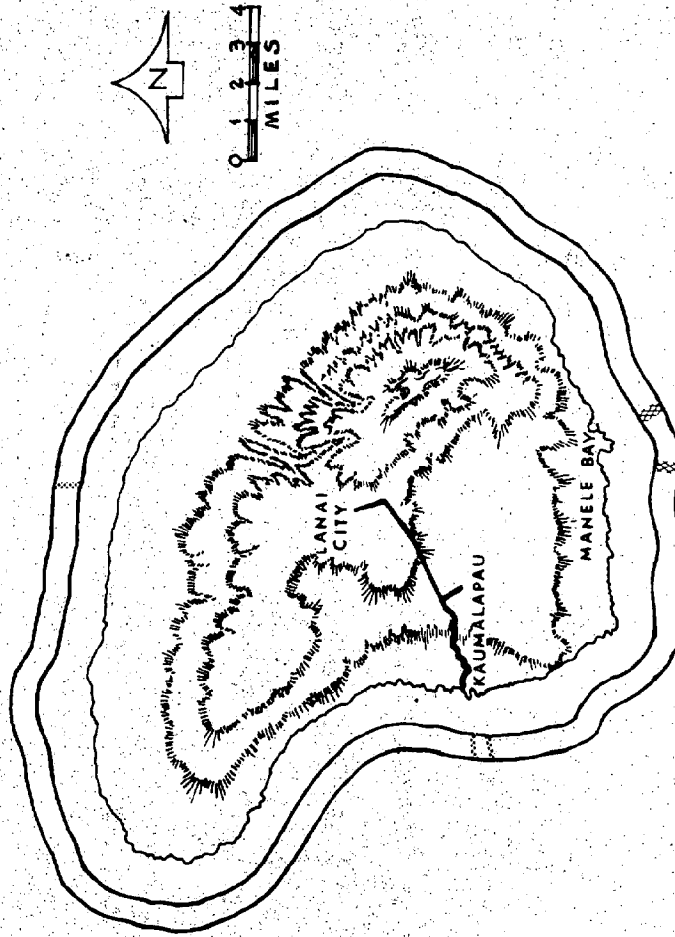
L e g e n d

-  SAND
-  GRAVEL
-  MUD (SILT & CLAY)
-  ROCK
-  ARTIFICIAL STRUCTURE
-  NON-CRITICAL EROSION OF N x 1000 FT. OF SHORELINE
-  CRITICAL EROSION OF N x 1000 FT. OF SHORELINE







SHORELINE PHYSICAL CHARACTERISTICS
SHORELINE EROSION AREAS
ISLAND OF LANAI

SHORELINE LAND USE ISLAND OF LANAI



LEGEND

-  PUBLIC RECREATIONAL
-  PRIVATE RECREATIONAL
-  NON-RECREATIONAL DEVELOPMENT
-  UNDEVELOPED

LAND OWNERSHIP — 1962

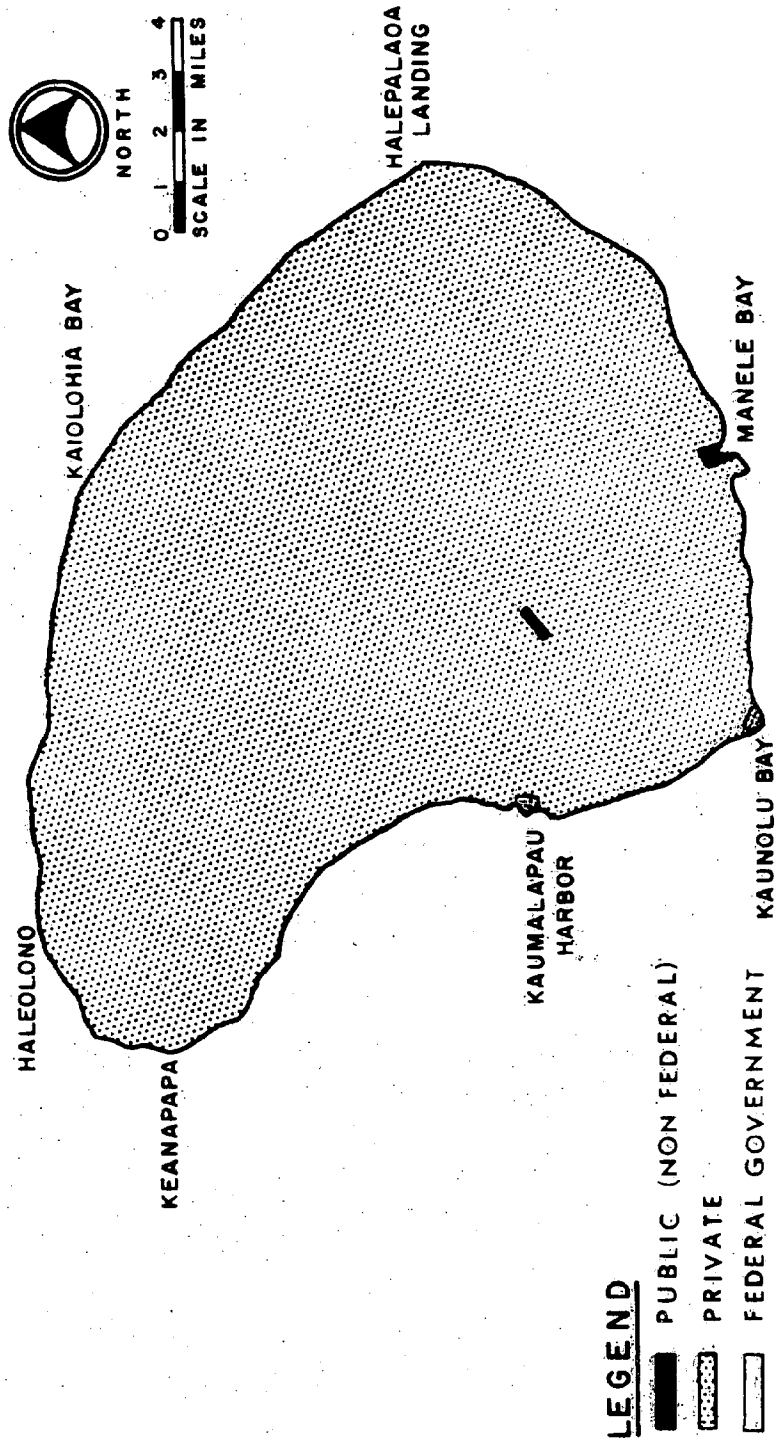


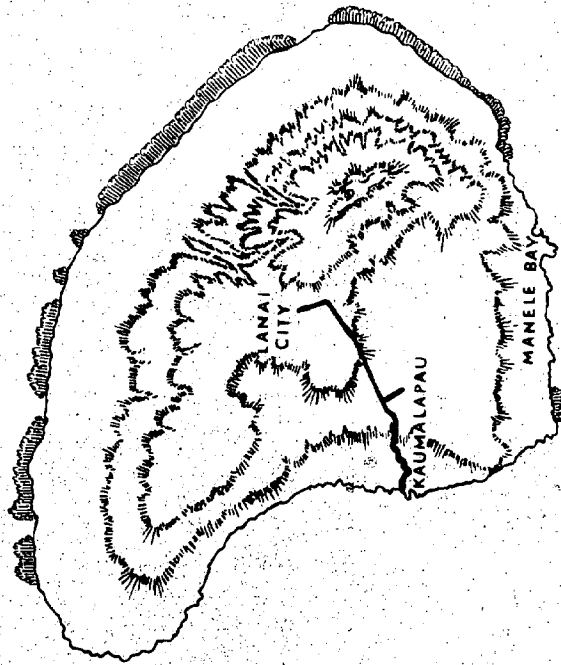
PLATE 26

LEGEND

CORAL REEF EXPOSED
AT MEAN
LOWER LOW WATER



0 1 2 3 4
MILES



**CORAL REEF
ISLAND OF LANAI**

ISLAND OF MAUI

GENERAL

The island of Maui is of volcanic origin and consists of two major volcanic cones, the East Maui cone or Haleakala Volcano and the West Maui cone, which are separated by an eight-mile wide isthmus formed by overlapping lava flows. Urban areas have been developed along physically accessible reaches of the coast and along the lower slopes of both volcanoes. The higher slopes are used primarily for watershed areas, ranches, and small farms.

The tidal shoreline is 159 miles long, about 59 percent of which is marginally or wholly inaccessible by land. The characteristics of the shoreline are summarized in table 18 and shown on plate 28.

Table 18
Shoreline Characteristics
Island of Maui
(1962)

Characteristics	Statute Miles	Percent
Rock	110.2	69.4
Gravel	11.2	7.1
Sand	33.7*	21.2
Mud (Silt and Clay)	0.0	0.0
Artificial structure	3.7	2.3
Total	158.8	100.0

*Includes 1.1 miles of seasonal sand beaches where the predominant beach material is sand for only a part of the year.

Source: "Hawaii's Shoreline" prepared by the State of Hawaii Department of Planning and Economic Development in 1965.

SHORELINE USE

Shoreline use in 1962 is shown on plate 29 and summarized in table 19 which shows that approximately 85 percent of the island's shoreline was undeveloped. However, this situation is changing primarily because of the rapid growth in tourism since development of a major tourist destination area at Kaanapali in West Maui. Current emphasis on tourism is increasing the demand for undeveloped shoreline reaches, particularly sandy beaches.

SHORELINE OWNERSHIP

Table 20 and plate 30, the latest data on shoreline ownership, show that more than half of the land abutting the island's shoreline are in private ownership. The land ownership pattern reflected in the table is expected to remain relatively static.

Table 19
Shoreline Land Use
Island of Maui
(1962)

Land Use	Total Shoreline		Sandy Beach	
	Miles	% of Total	Miles	% of Total
Recreational—Public	8.0	5.1	4.9	15.1
Recreational—Private	0.0	0.0	0.0	0.0
Non-Recreational				
Development	15.4	9.6	5.5	16.8
Undeveloped	135.4	85.3	22.2	68.1
Total	158.8	100.0	32.6	100.0

Source: "Hawaii's Shoreline", prepared by the State of Hawaii Department of Planning and Economic Development in 1965.

Table 20
Shoreline Land Ownership
Island of Maui
(1962)

Owner	Total Shoreline		Sandy Beach	
	Miles	% of Total	Miles	% of Total
Federal	1.4	0.9	0.0	0.0
Public (non-Federal)	60.7	38.2	10.3	31.6
Private	96.7	60.9	22.3	68.4
Total	158.8	100.0	32.6	100.0

Source: "Hawaii's Shoreline", prepared by the State of Hawaii Department of Planning and Economic Development in 1965.

PHYSICAL CHARACTERISTICS AND HISTORY OF SHORELINE

Table 21 describes the physical characteristics, ownership, use, and condition of the principal sandy beaches of Maui. The following discussion supplements the data in the table providing general descriptions of the physical characteristics of the island's shoreline and general evaluations of shoreline conditions. For this discussion, the island was divided into nine sections.

North-Central Shore (plate 31). The reach extending from Hakuhee Point to Maliko Bay is the most highly developed shoreline of the island. Kahului Harbor, the island's only commercial navigation harbor, and the contiguous towns of Wailuku and Kahului which comprise the business and population center of the island, are located along this coast.

The shoreline from Hakuhee Point to about a half

Table 21
Characteristics of Principal Beaches on Maui

Name	Stability Classification Length in 1,000 Feet			Length		Width Feet	Type of Beach		Predominant Beach Composition	Shore Ownership			Shore Use in Linear Feet		
	Critical Erosion	Non-Critical Erosion	Non-Eroding	Feet	Natural		Artificial	Federal		Non-Federal	Public	Recreational		Non- Recreational	Undeveloped
												Public	Private		
North Central Shore															
Waiehu Beaches	3	12		15,000	35	X			Calcareous		N ¹		2,000	5,000	8,000
Kailua-Halea	1	1		3,600	120	X			"		N			1,600	10,000
Spree-Kieselle	3	10		13,000	50	X			"		X			3,000	
Baldwin		2		2,000	75	X			"					2,000	
Pala (Lower)		2		2,000	80	X			"					2,000	
Northeast Shore															
Hana		1		700	100	X			Volcanic		X		700		
Southeast Shore															
Hanalei		1		1,000	100	X			Calcareous					1,000	
South Shore															
Puu Ohi		3		3,300	100	X			"						3,300
Puu Ohi to Kamaole Park	4	12		16,000	60	X			"						16,000
Kamaole Park		4		1,000	60	X			"		X		1,000		
Kalama Park		4		4,000	30	X			"		X		4,000		
South Central Shore															
Kihui Beaches	4	3	8	15,000	100	X			"		X ²		3,000	5,000	7,000
Olowalu	3	3		6,000	40	X			"		X				6,000
Northwest Shore															
Makila		1		1,200	35	X			"		X				1,200
Lahaina Residential Beach	2	5		7,000	30	X			"						7,000
Hanalei Point	6	6		12,000	50	X			"						12,000
Kaanapali	4	1		8,000	100	X			"					8,000	
North Shore															
Napili		1		1,000	100	X			"					1,000	
Flemings		1		700	90	X			"				700		
Honokahua		2		1,500	160	X			"						1,500

¹7,000 Ft. Public, 8,000 Ft. Private

²3,000 Ft. Public, 12,000 Ft. Private

mile north of Waihee is an undeveloped, physically inaccessible reach characterized by sea cliffs and the absence of an offshore reef. The shoreline extending south to Kahului Harbor consists of rugged terrain behind hills of dissected alluvial fans and older dunes, and lowlands of alluvium and shoreline deposits. Although low in elevation, the reach north of Waihee has no sand beaches. The reach of consolidated and unconsolidated alluvium south of Waihee is fronted by a narrow beach of poorly sorted sand and gravel.

The 15,000-foot-long, 35-foot-wide, slightly arcuate beach at Waiehu is about a mile north of the mouth of Iao Stream. Sand along this beach is well sorted, very coarse in grain size, and is composed of equal amounts of volcanic and calcareous material. Vegetated sand dunes lie between the beach and its marshy hinterland.

An increase in the detrital portion of beach sediment occurs along the reach fronting a swamp between Waiehu and Iao Stream.

Artificial structures comprising the Kahului Deep-Draft Harbor line most of the shoreline within Kahului Bay. The existing harbor consists of a 2,315-foot-long west breakwater; a 2,760-foot-long east breakwater; a 600-foot-wide entrance channel between the breakwaters; a 2,400-foot-long, 2,050-foot-wide and 35-foot-deep harbor basin; a revetted spoil disposal area behind the west breakwater; and two concrete wharves on concrete piles on which are built storage sheds and other port facilities. Two beaches at the head of the bay are separated by a revetment fronting a cluster of hotels. The beaches are composed of a mixture of sand and gravel.

Waihee Reef, the most prominent offshore feature along the north central coast, extends from Waihee Point to Kahului Harbor. It is about 1,000 feet wide off Waihee and narrows to about half this width near Kahului.

Spreckelsville Beach, a 13,000-foot-long reach east to Kahului Harbor is broken into a series of short beaches by points of lava, boulders, and beachrock, and by manmade groin systems which were constructed to retain sand along this reach. The beach sand is poorly sorted, with a bimodal distribution of calcareous grains ranging in size from cobble-sized coralline gravel to medium-sized sand grains. Large sand dunes lie behind the beach which is about 50 feet wide but varies in width due to natural causes and because of sand mining operations at the west end. Lines of beachrock exposed at the waterline about 800 feet offshore define the limits of a former shoreline, and are evidence of continued erosion over the years. An alongshore current to the west prevails except during southerly storms when the current is reversed.

The reach extending from Papaula Point to Maliko Bay is characterized by alternating stretches of lava

basalt and sandy beaches, the larger of which are at Baldwin Park and Lower Paia. The 2,000-foot-long, 75-foot-wide beach fronting Baldwin Park is primarily composed of calcareous sand. The beach fronting the town of Lower Paia is slightly arcuate and about 2,000 feet long and 80 feet wide. The sand is moderately well sorted, and composed almost entirely of fragments of calcareous origin.

North-Northeast Shore (plate 31). The shoreline extending from Maliko Bay to Keanae Point is an inaccessible, irregular reach of sea cliffs broken by a number of bays, some of which are partly drowned river valleys. The sea cliffs rise from less than 100 feet at the west end to 400 feet near Honomanu Bay. Sandy beaches exist only at the head of Honomanu and Nuaailua Bays at the east end of this reach. However, some of the other bays have shingle pocket beaches.

A broad, two-mile-wide headland at Keanae Point, formed by lava which flowed into the ocean from Haleakala, supports a small farming community. The sea cliffs around this headland are about 5 to 10 feet high. Except for the relatively isolated community at Keanae and a Coast Guard reservation at the west end, this coast is undeveloped. There are no reefs along this coast; however, sea stacks are common.

Northeast Shore (plate 31). Except for an airport and rural communities at Wailuanui and Hana Bays, the reach extending from Keanae Point to Hana Bay is undeveloped. The shoreline is characterized by sea cliffs, most of which are between 20 and 30 feet high, except near Kapukaula where they rise to 200 feet. Pocket beaches exist at some of the bays and coves; however, except for the beach at Hana, they are only marginally accessible by land.

The 700-foot-long, 100-foot-wide beach on the southern shore of Hana Bay is bound by a lava point at the northwest end and by highway fill to the southeast. Sand along this slightly arcuate beach is well sorted and fine-grained. About three-fourths of the sand consists of detrital grains of fresh and weathered lava while about one-fourth is of calcareous origin. A seawall along the backshore provides protection for the beach park behind it. Offshore, the sand continues at a gentle slope to a reef area in the northern part of the bay.

The shoreline at the southeast boundary of Hana Beach has been altered by construction of a T-shaped pier which extends seaward from the highway fill. The pier provides about 300 feet of berthing space for small craft and commercial tugs and barges which call at this relatively isolated community. Plans for a small boat harbor at the northwest end of the bay have been prepared by the Corps of Engineers and approved for construction by Congress. However, construction funds have not been appropriated. This

Federal project consists of construction of a 1,230-foot-long rubblemound breakwater, the landward 250 feet of which would be a revetted mole. This structure would shelter a turning area and harbor basin of about 200,000 square feet. Terminal and berthing facilities for the harbor would be constructed by the State of Hawaii.

Southeast Shore (plate 32). The reach extending southwest from Hana Bay to Mamalu Bay is undeveloped except for a few small rural communities. Hamoa Beach at the head of Mokae Cove is one of several pocket beaches at the east end of this reach. The 1,000-foot-long, 100-foot-wide beach is bound by 30-foot-high cliffs at both ends. The sand is well sorted, medium and fine in grain size, and composed of calcareous fragments. It is 6 feet thick at mean lower low water, and even thicker towards the backshore which is occupied by a private surf club.

Sea cliffs ranging in height from 50 to a few hundred feet dominate the reach west of Hamoa Beach. Beaches are rare and are primarily shingles of coral and basalt pebbles. The existence of sea stacks and sea caves attest to the occurrence of erosion along this coast. Although isolated coral heads are abundant, there are no exposed fringing coral reefs (plate 33).

South-Southeast Shore (plate 32). An extremely irregular shoreline composed of relatively young lava basalt extends along the undeveloped and marginally accessible reach between Apole Point and La Perouse Bay. Sandy beaches exist only at Nu'u and Huakini Bays at the east end of this reach, and at the northwest end of La Perouse Bay.

South Shore (plate 32). Except for the urban development of south Kihei, the reach from La Perouse Bay to Kalama Park has been essentially undeveloped. The shoreline from Makena to Keawakapu is now scheduled for extensive resort development. The southern third of this reach is characterized by low cliffs of young lava basalt and is only marginally accessible by land. The northern two-thirds consists of a series of crescentic beaches between low, sea-cliff lava points. The largest of these beaches lies south of the Puu Olai cinder cone, and is 3,300 feet long and 100 feet wide. It is predominantly composed of a poorly sorted mixture of almost all sand sizes of calcareous material, and includes some fine gravel sizes as well. Dunes covered with kiawe trees form the backshore. The foreshore is steep, a result of large waves which frequently strike the beach.

Makena Beach, another of the series of crescentic beaches along this coast, is 1,000 feet long and bound by lava points at each end. The sand is calcareous, well sorted, and coarse in grain size. Extensive dunes covered with kiawe trees occupy the backshore. The offshore area is rocky, with a thin veneer of sand overlying it. Sand is also found in

scattered pockets.

The slightly arcuate beach at Keawakapu is more than 2,000 feet long and is bound by lava outcrops at both ends. The sand is fine-grained, well sorted, and almost entirely calcareous. It tends to move onshore and offshore during the year. Some sand is also blown inland and lost. During the winter of 1962-63, the beach was severely eroded by repeated storms from the south, which resulted in considerable damage to private beach homes on the low sandy terrace behind the beach. Thick sand lies off the middle section of the beach. A coral reef lies off the north end, and lava predominates off the south end.

Kalama Beach Park lies at the south end of a narrow, almost continuous beach which extends to the north of Kihei. The beach fronting the public park is 4,000 feet long, 30 feet wide, and is composed of very poorly sorted sand and gravel sediment primarily of calcareous origin, with only a small percentage of volcanic fragments. Although seasonal accretion and erosion occur at this beach, the net effect has been erosion. Surveys made of this beach in 1912 and 1961 showed that the shoreline receded 300 feet during this 49-year period, and has impaired the recreational usefulness of the beach park. In addition, the erosion threatened the highway embankment at the south end of the park and necessitated construction of a revetment of 500-pound stone topped with larger-sized concrete block components. The severity of the erosion problem warranted Federal participation in a beach erosion control project which is currently under construction. The project provides for construction of a 25-foot-wide berm along the length of the park, and a 3,000-foot-long revetment seaward of the berm. The sloped revetment would protect the berm from erosion, and should encourage accretion of sand on the seaward side.

South-Central Shore (plate 32). This reach extends from the north end of Kalama Park to Olowalu Wharf. Except for a small boat harbor and residential and condominium developments along the shores of Maalaea Bay, and a few scattered residences at Olowalu, much of the shoreline fronting this reach is undeveloped.

A number of locations along the Kihei shores at the southeast end of Maalaea Bay have a history of erosion while other areas within this reach have accreted. In the Keokea homesteads area north of Kalama Park, residents have constructed seawalls to protect their properties from erosion. These structures have been relatively effective against local erosion, although a 75-foot-long wall was 8 feet seaward of the high water line in 1967. Surveys made of the south Keokea area in 1912 and 1964 showed that an average annual erosion rate of 1.48 cubic yards per foot of shore occurred during this 52-year period. In

the north Keokea area, the annual rate of erosion was 0.07 cubic yard per foot of shore.

Substantial accretion has occurred along a 1.5-mile reach of shoreline between Keokea and Kalepolepo. Comparison of surveys made in 1912 and 1961 shows that up to 200 feet of accretion had occurred in places within this reach.

Artificial structures, primarily the seawalls of two old Hawaiian fishponds, line the short reach of shoreline fronting Kalepolepo. The southernmost pond covers 38 acres and consists of a semicircular rubble wall which extends 1,100 feet seaward with a land frontage of 1,700 feet. The pond has not been used for years and the wall has almost completely deteriorated, although some rocks are visible above water at low tide. The area within the smaller pond to the north had become dryland some time before 1900. However, around 1910 the old fishpond wall was breached and about half of the fill washed out to sea. The pond is about 800 feet wide and the outer wall is now about 250 feet from shore. The shoreline at the north end of this pond experienced severe erosion between 1900 and 1964. Surveys showed an average annual erosion rate of 2.5 cubic yards per foot of shore during this 64-year period.

The shoreline from Kalepolepo to Kihei Memorial Park has also experienced critical erosion. Surveys show an average annual erosion rate of 1.92 cubic yards per foot of shore for the reach between Kalepolepo and the public park, and 1.04 cubic yards per foot for the beach fronting the park. In 1963 the County of Maui constructed a wooden wall in front of the park pavilion to protect it from being undermined by erosion. In 1964, the County also constructed a 200-foot-long revetment to protect the highway at the south end of the park. One-ton rock was placed to a crest height of about 8 feet above mean lower low water with a seaward slope of about 1 on 1.5.

The northern boundary of the Kihei shores is defined by the remains of the old Kihei wharf. This wharf was originally 200 feet long, and provided fair-weather accommodations for small craft, particularly fishing vessels. It was abandoned in 1952 following construction of the Maalaea Boat Harbor at the southwest end of the bay. The outer portion of the wharf has since been destroyed by storms, and only about a 130-foot-long rubblemound stub remains.

The shoreline extending along the head of Maalaea Bay, between the old Kihei Wharf and the Maalaea Boat Harbor, is a barrier beach with an average width of 75 feet. Outcrops of beachrock occur along the beach which is composed of a mixture of calcareous fragments and detritus. Low sand dunes separate the beach from Kealia Pond, a salt water marsh at the northeast end of the bay. Part of the marsh is being used as a commercial shrimp farm.

In 1952, the shoreline at the northwest end of

Maalaea Bay was altered by construction of a recreational boat harbor by the State of Hawaii. Several modifications have been made since that time such that the harbor presently consists of a 100-foot-wide, 12-foot-deep entrance channel; a 7.5-acre, 12-foot-deep harbor basin; a 1,000-foot-long combination breakwater and mole structure; an 840-foot-long breakwater; a 308-foot-long, 50-foot-wide paved wharf; berthing facilities for 43 boats; and a launching ramp.

The shoreline from the small boat harbor to about 2 miles west of Papalaua Point is characterized by sea cliffs in contrast to the low coast on both sides. The sea cliffs between the boat harbor and Papalaua Point are relatively low, and contain a few tiny pocket beaches. The cliffs west of Papalaua Point are generally higher and are bordered at the base by a terrace about five feet above sea level. Sea stacks dot the offshore areas of this reach. Deep water occurs close to land, particularly around Papalaua Point, but becomes shallower at both ends of the reach.

The low coast extending to Olowalu Wharf consists of alternating stretches of narrow sandy beaches and lava outcrops.

Northwest Shore (plate 32). This reach between Olowalu and Napili is one of the most rapidly growing areas on the island. Developments along the shoreline include the urban area of Lahaina, once the capital of Hawaii and now a popular tourist attraction, and the resort area at Kaanapali. Often referred to as the Lahaina-Kaanapali area, this rapidly developing reach is the principal tourist destination center of the island.

The shoreline between Olowalu and Lahaina has five sandy beaches between stretches of lava outcrops. The beaches are narrow, and have a total length of between 7,000 and 8,000 feet. Makila Beach is typical of the beaches within this reach. During the year, the 35-foot-width of this beach hardly changes. However, the ratio of sand to gravel and boulders changes markedly. The sediment is an extremely poorly sorted mixture of both volcanic and calcareous grains of all sizes. A coral reef extends offshore, and is covered with gravel and boulders, but very few patches of sand.

The reach from Lahaina to Mala Wharf is characterized by alternating reaches of sandy beaches and artificial structures, including seawalls, a small boat harbor, and an abandoned wharf. The Lahaina Boat Harbor is an 80,000-square-foot harbor fronting the center section of the town (figure 28). It is protected by a 1,000-foot-long breakwater which is seated on the fringing coral reef. The harbor which has a launching ramp and capacity for 80 small boats, is inadequate for the growing recreational boat population of the area, and plans are underway for construction of a new harbor by the Corps of

Engineers in response to a request from the State of Hawaii. The new harbor would be located about 2,000 feet northwest of the existing harbor.

The reach extending from the badly deteriorated and abandoned Mala Wharf to Hanakao Point consists of alternating stretches of beachrock and sandy beaches. The 12,000-foot-long, 50-foot-wide beach at Hanakao Point is the most significant of the beaches within this reach. The beach is generally subject to seasonal accretion and erosion. However, during the past few years, critical erosion has occurred along the northern half of the beach, and has undermined a wooden triangulation tripod at the point.

The 8,000-foot-long, 100-foot-wide beach at Kaanapali is immediately north of Hanakao Beach. Kekaa Point, a littoral cinder cone now covered with resort buildings, lies at the south end of this beach which is subject to seasonal accretion and erosion (figure 29). Beach sand is well sorted, medium-sized grains of predominantly calcareous fragments. Rock ridges and sand pockets alternate offshore. A well-developed berm and a moderately steep foreshore which are

characteristic of the profile for this beach, are evidence of the seasonal occurrence of large swells.

North Shore (plate 31). The reach of sea cliffs between Napili and Hakuhee Point is one of the most scenic on Maui. Except for two Coast Guard reservations, resort hotels along Napili Bay, and small urban developments at the east and west ends, the shoreline along this coast is undeveloped.

The western third of this coast consists of sea cliffs 20 to 30 feet high with several rocky points. A few small sandy beaches exist in pockets between these points. One such beach is the 1,000-foot-long, 100-foot-wide beach at the head of Napili Bay. Bound by rocky cliffs at both ends, this slightly arcuate beach is composed of well sorted, medium-sized grains of calcareous sand. It is subject to some erosion, particularly during the winter. A coral reef with large sand pockets lies offshore.

The 700-foot-long, 90-foot-wide Flemings Beach is another of the pocket beaches along the western end of the north shore (figure 30). The beach terminates

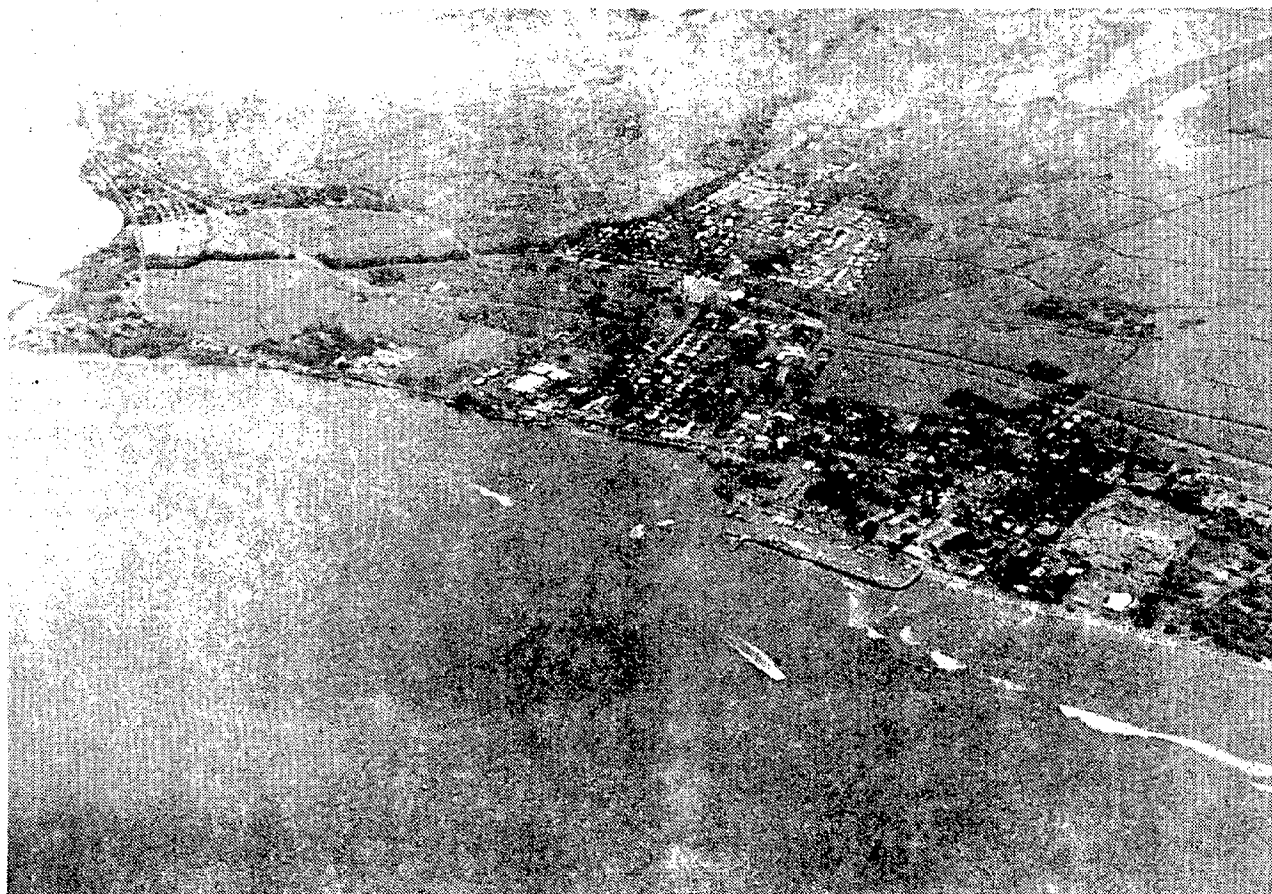


Fig. 28 Aerial view of Lahaina Boat Harbor, Maui

against rocky points of lava at both ends, and is composed of well sorted, coarse, predominantly calcareous sediment.

Honokahua Beach is a 1,500-foot-long, 160-foot-wide straight beach between points of lava. It is composed of well sorted, medium-sized grains of calcareous sand. Ironwood trees grow on the large dunes along the backshore. A thick layer of sand lies offshore.

The middle third of the north shore consists of sea cliffs 50 to 300 feet high. Small sand beaches occur at Keonehelele and Honokohau Bays. Boulder and cobble beaches can be found at the heads of some of the bays, particularly near stream mouths.

Sea cliffs along the eastern third of the north shore range up to 600 feet in height. Some of the cliffs have near-vertical faces 200 to 300 feet high.

SUMMARY

Approximately 5.7 of the 158.8 miles of shoreline around the island of Maui have been critically eroded; about 14.8 miles have a history of erosion but the problem is not critical at this time; and the remaining 138.3 miles have a history of stability or accretion.

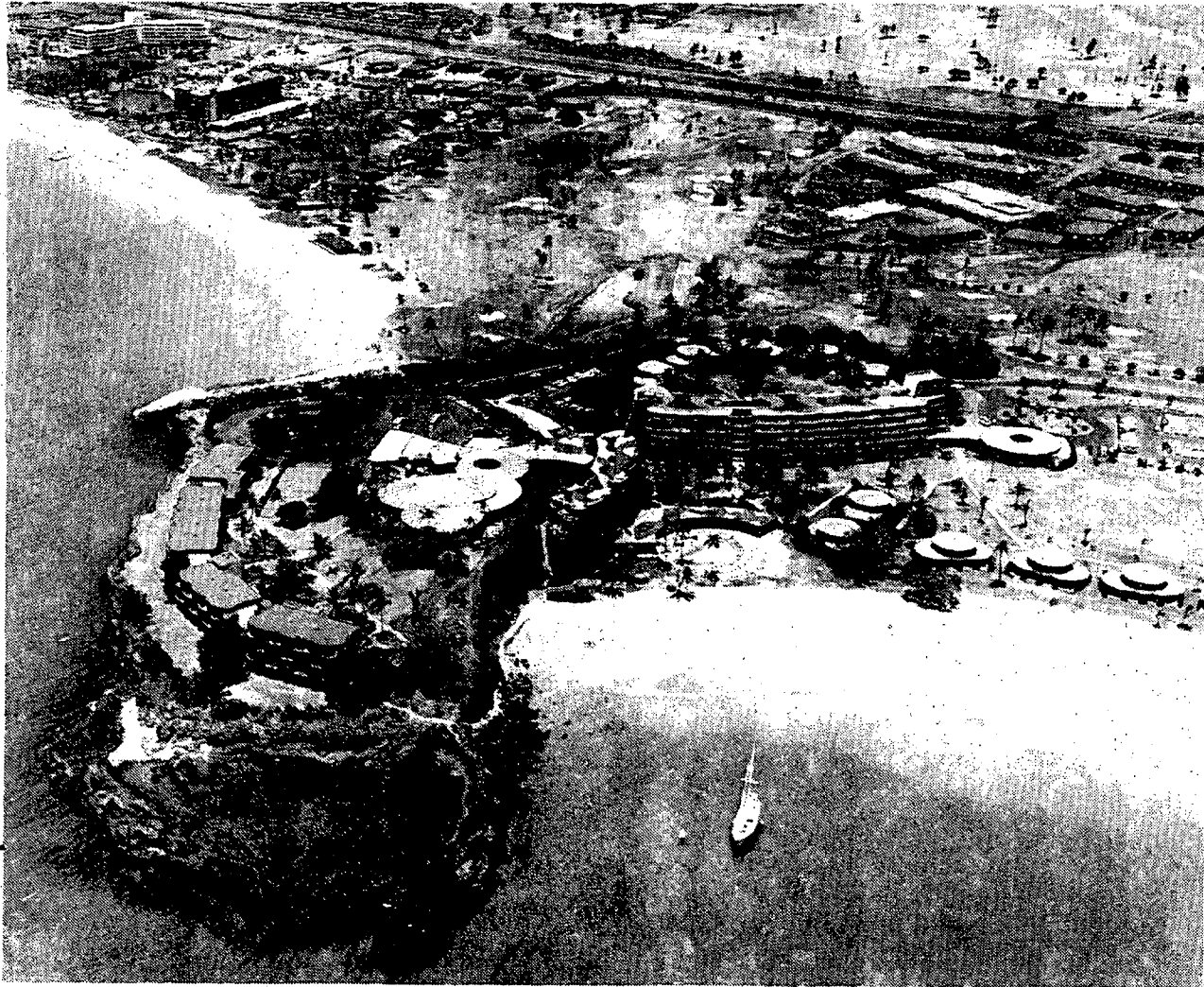


Fig. 29 Aerial view of Kaanapali Coast, Maui (Camera Hawaii Photo)



Fig. 30 *Flemings Beach, Maui (Camera Hawaii Photo)*

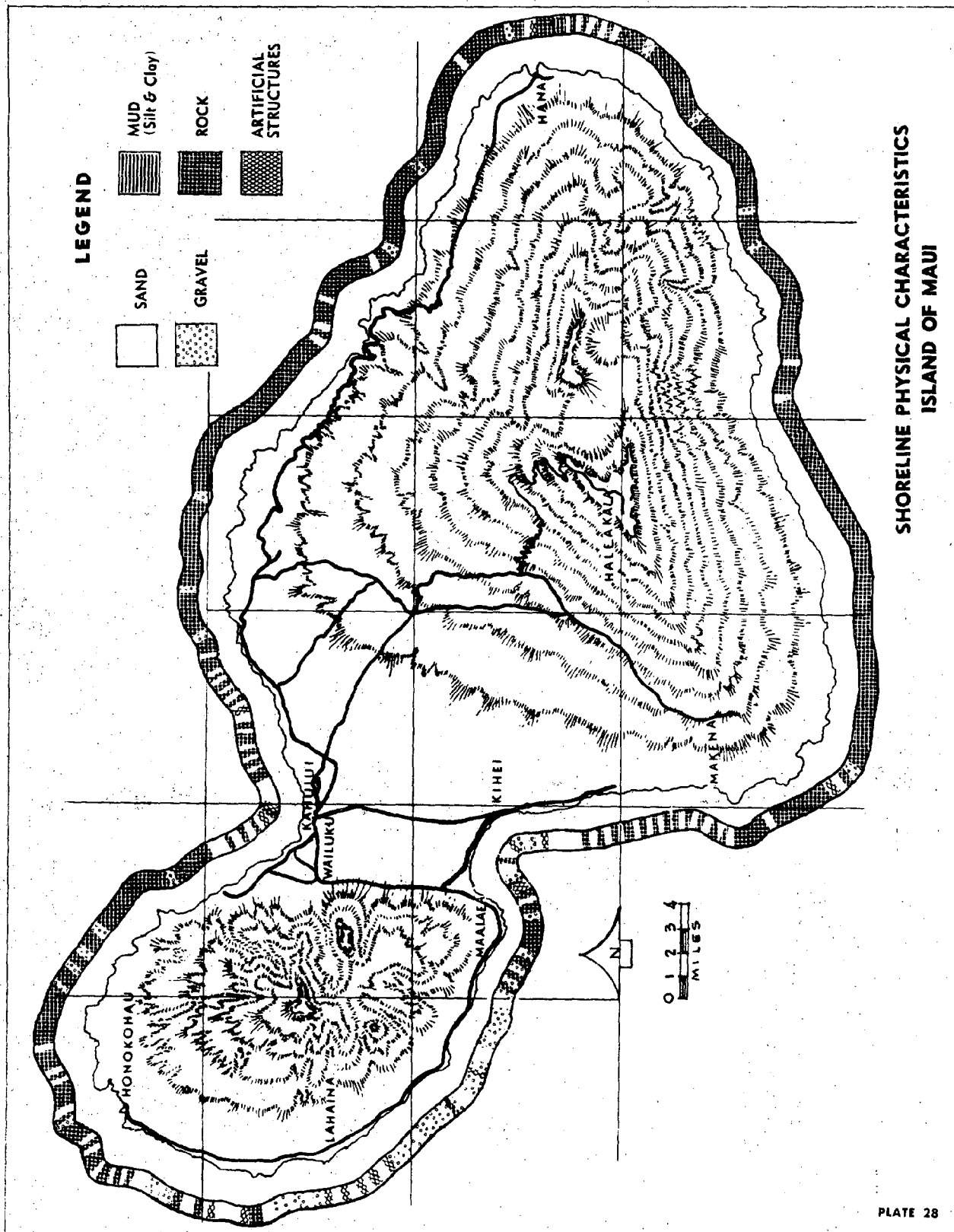


PLATE 28

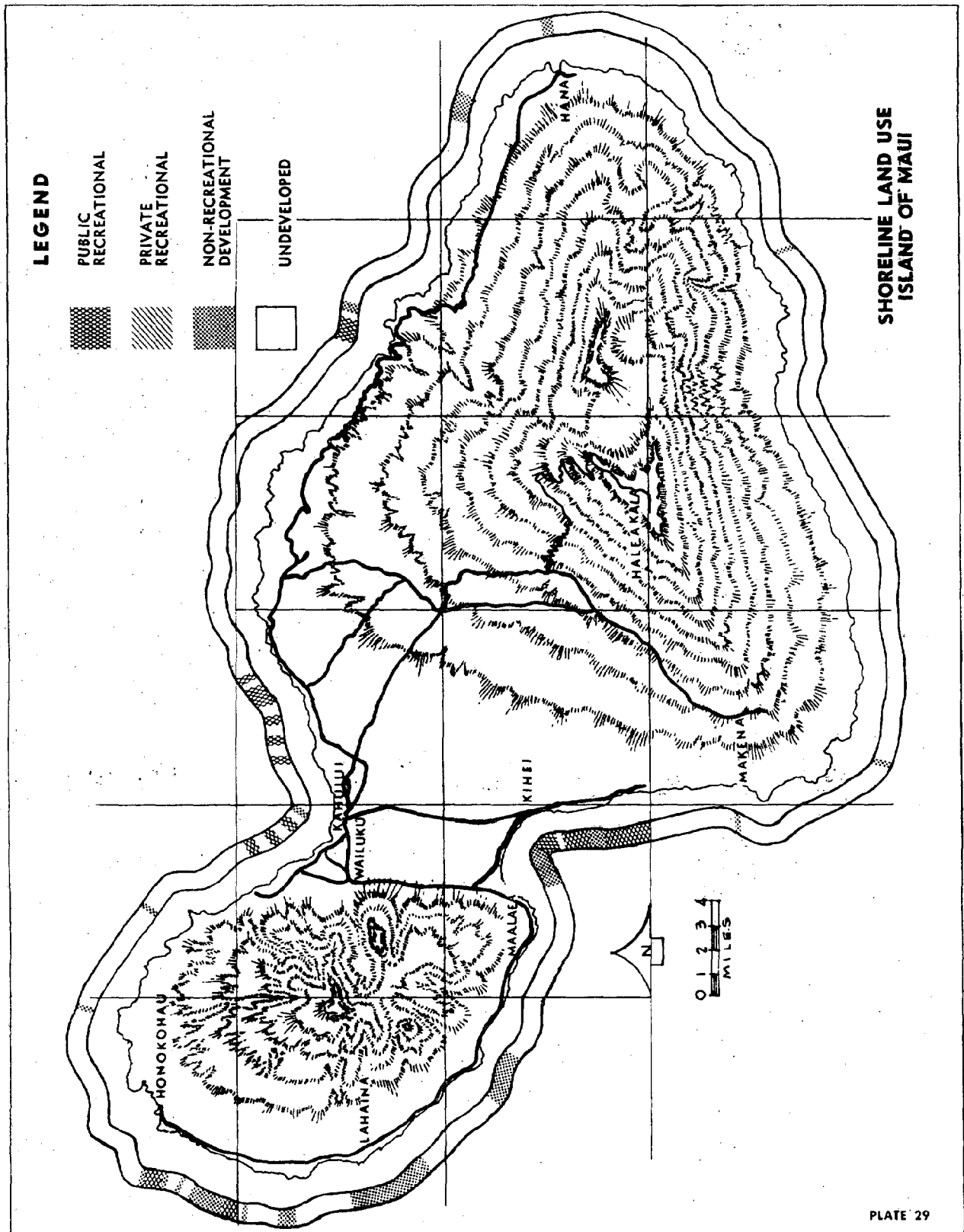


PLATE 29

LAND OWNERSHIP — 1962

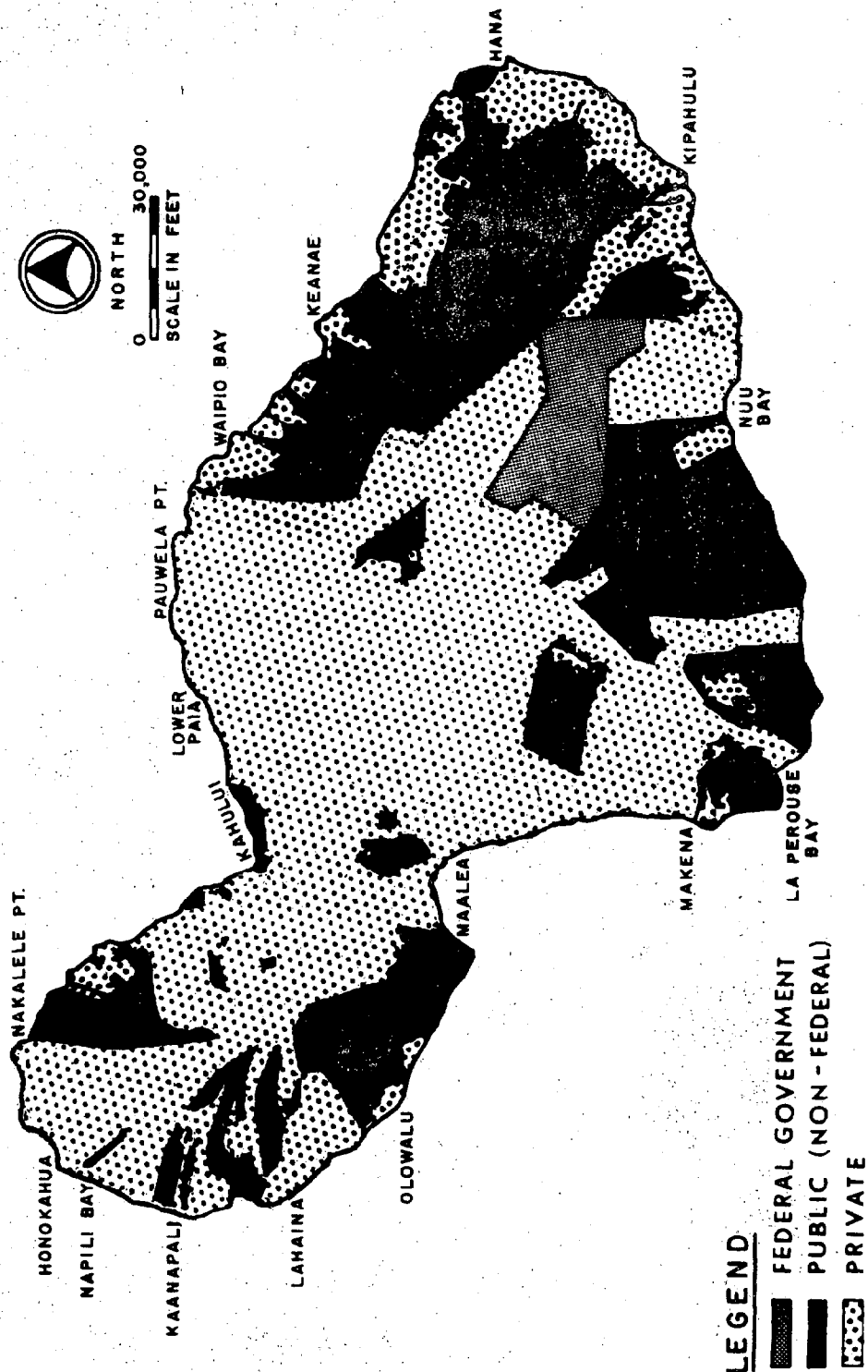


PLATE 30

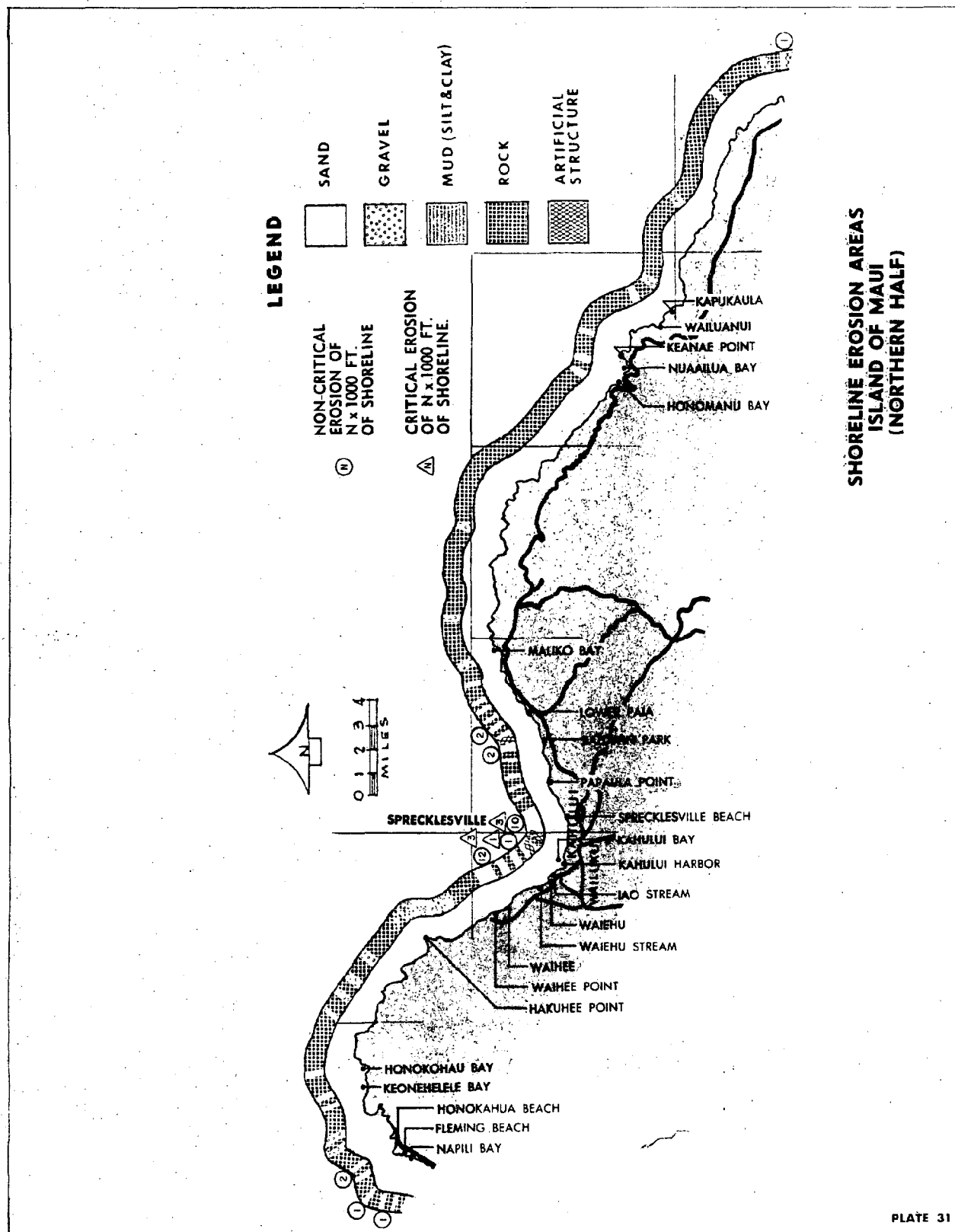
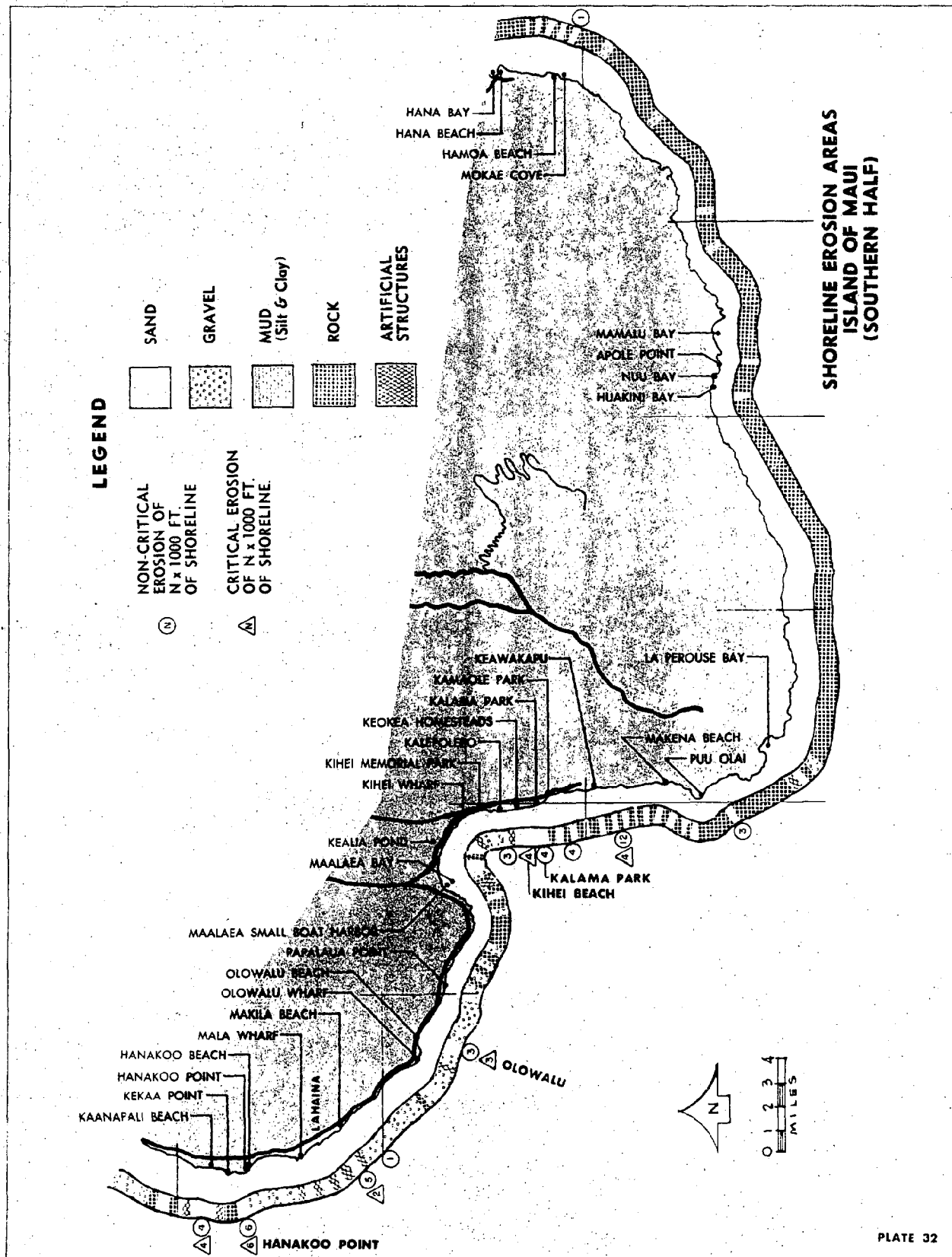


PLATE 31



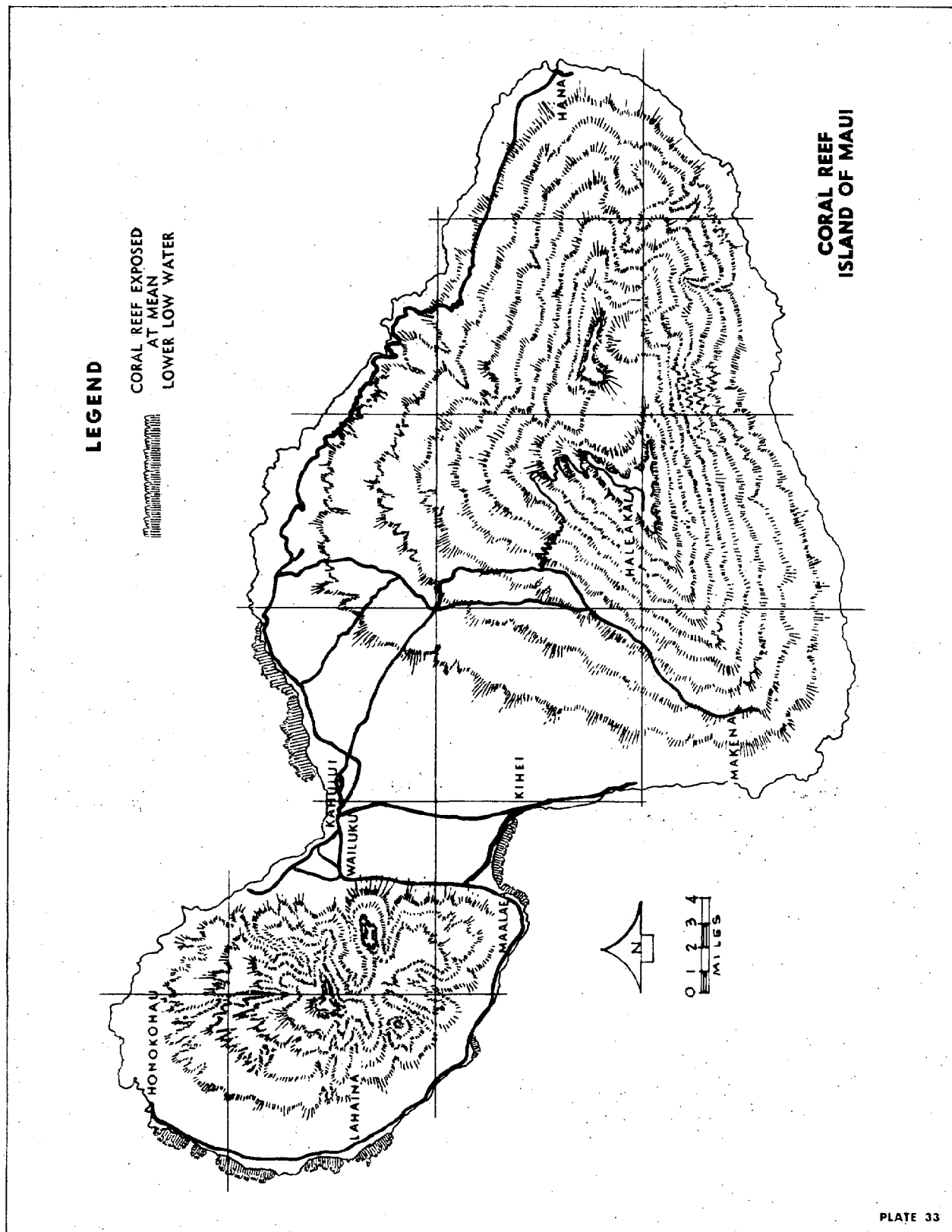


PLATE 33

ISLAND OF HAWAII

GENERAL

The island of Hawaii, known as the "Big Island", is larger than all of the other islands combined. Its land area of 4,030 square miles comprises 62 percent of the land area of the state. The island is of volcanic origin, and was formed by the gradual emergence and subsequent coalescence of five volcanoes, two of which, Mauna Loa and Kilauea, are still active.

The tidal shoreline is 306 miles long, and is 50 percent greater than that of Maui, the next largest island. About 90 percent of this coastline is rock, 80 percent of which is marginally or wholly inaccessible by land. Sandy beaches are relatively rare, and are only slightly more than that on Lanai. The characteristics of the island's shoreline are summarized in **table 22** and shown on **plate 34**.

Table 22
Shoreline Characteristics
Island of Hawaii¹
(1962)

Characteristics	Miles	Percent
Rock	274.7	89.9
Gravel	5.1	1.6
Sand	21.8*	7.2
Mud (Silt and Clay)	0.0	0.0
Artificial structures	3.9	1.3
Total	305.5	100.0

¹Offshore islands excluded.

*Includes 2.4 miles of seasonal sand beaches where the predominant beach material is sand for only a part of the year.

Source: "Hawaii's Shoreline" prepared by the State of Hawaii Department of Planning and Economic Development in 1965.

SHORELINE USE

Like all of the other islands except Oahu, the shoreline of the island of Hawaii is primarily open, undeveloped land (**plate 35**). **Table 23** shows that non-recreational development comprises the second largest use of the shoreline. Except for Hilo and Kailua-Kona, urban development along the coastal zone consists of scattered plantation towns and villages.

SHORELINE OWNERSHIP

Table 24 and **plate 36**, the latest data on shoreline ownership, show that private landholders control the largest percentage of Hawaii's shoreline. Although

the land ownership pattern reflected in the table is not expected to change drastically, it is expected to be more dynamic than other islands of the state because of the current emphasis on tourism and resort development.

Table 23
Shoreline Land Use
Island of Hawaii¹
(1962)

Land Use	Total Shoreline		Sandy Beach	
	Miles	% of Total	Miles	% of Total
Recreational—Public	11.0	13.4	0.6	3.1
Recreational—Private	0.0	0.0	0.0	0.0
Non-Recreational				
Development	16.1	15.3	1.3	6.7
Undeveloped	278.4	71.3	17.5	90.2
Total	305.5	100.0	19.4	100.0

¹Offshore islands excluded.

Source: "Hawaii's Shoreline" prepared by the State of Hawaii Department of Planning and Economic Development in 1965.

Table 24
Shoreline Land Ownership
Island of Hawaii¹
(1962)

Owner	Total Shoreline		Sandy Beach	
	Miles	% of Total	Miles	% of Total
Federal	31.5	10.3	0.0	0.0
Public (non-Federal)	102.5	33.6	7.8	40.2
Private	171.5	56.1	11.6	59.8
Total	305.5	100.0	19.4	100.0

¹Offshore islands excluded.

Source: "Hawaii's Shoreline" prepared by the State of Hawaii Department of Planning and Economic Development in 1965.

PHYSICAL CHARACTERISTICS AND HISTORY OF SHORELINE

Table 25 describes the physical characteristics, ownership, use, and condition of the principal sandy beaches of Hawaii. The following discussion supplements the data in the table by providing general descriptions of the physical characteristics of the shoreline of Hawaii, and qualitative assessments of shore-

Table 25
Characteristics of Principal Beaches on the Island of Hawaii

Name	Stability Classification Length in 1,000 Feet			Length Feet	Width Feet	Type of Beach		Predominant Beach Composition	Shore Ownership			Shore Use in Linear Feet			
	Critical Erosion	Non-Critical Erosion	Non-Eroding			Natural	Artificial		Federal	Public Non-Federal	Private	Recreational		Non- Recreational	Undeveloped
												Public	Private		
East Shore															
Hilo Bay	1			400	35	X		Volcanic		X				100	
Southeastern Shore															
Kaimu Black Sands	1			1,000	75	X		Volcanic		X				1,000	
Kalapana (Harry K. Brown Park)		1		900	100	X		Volcanic		X		900			
Punaluu Beach Park	1			900	70	X		Volcanic		X		900			
Southwest Shore															
Hookena Beach Park		1		600	100	X		Volcanic		X		600			
Kealahou		1		600	60	X		Calcareous			X		600		
Northwest Shore															
Disappearing Sands Beach		—		300	50	X		Calcareous		X		300			
North Kona Beaches	8	7		15,000	100	X		Calcareous		X ¹	X ¹			15,000	
Hapuna		2		2,200	160	X		Calcareous		X ²	X ²	1,200	1,000		
Mauna Kea		—		300	100	X		Calcareous			X			300	
Spencer Beach Park		—		100	160	X		Calcareous		X		100			
Northeast Shore															
Pololu Valley		1		1,200	125	X		Volcanic		X				1,200	
Waipio Valley		4		4,000	200	X		Volcanic			X			4,000	

17,500 Ft. Public, 7,500 Ft. Private.

11,200 Ft. Public, 1,000 Ft. Private.

line conditions. For this discussion, the island was divided into 5 sections.

East Shore (plate 37). This reach extends south from Waipio Valley to Cape Kumukahi. The northern half of this reach is primarily in agriculture, and the southern half is basically undeveloped. Hilo, the principal city of the island is located along the center section of this reach.

The shoreline between Waipio Valley and Hilo Bay consists of sea cliffs which are from 100 to 200 feet high. A few small boulder beaches exist in small coves, and a terrace about five feet above mean sea level is present along much of the coast.

Hilo Bay is a large bight in the center of this reach. The south and east shores of the bay are relatively flat and at low elevations, while the west shore is a rock bluff. The entrance to the bay lies between the bluff and a coral reef known as Blonde Reef, and is about one mile wide. The reef extends northwesterly from the southeast side of the bay and provides partial protection to the inner bay, creating a natural deep-water harbor. This site was developed into a commercial navigation harbor in 1930. Modifications since that time have made Hilo Harbor the second largest seaport in the state. The existing harbor consists of a 10,080-foot-long rubblemound breakwater, a 35-foot-deep entrance channel, and a 1,400-foot-wide, 2,300-foot-long, and 35-foot-deep harbor basin. Terminal facilities include two piers, sheds, and pipelines for petroleum products, liquid fertilizer, and molasses, all of which are owned by the State of Hawaii.

The Waiakea Peninsula west of Hilo Harbor separates the harbor from the Wailoa Sampan Basin near

the mouth of the Wailoa River. This basin provides the only accommodations for commercial fishing vessels operating along the east coast of the island.

A small beach averaging only about 400 feet long and 35 feet wide fronts Mōoheau Park along the center section of the shoreline of Hilo Bay. The beach is bound by highway fill at its eastern and western ends, and is composed almost entirely of volcanic rock fragments of sand size, with very few calcareous components. The sand exhibits moderately good sorting at about a medium-grain size. The present beach is the remnant of what was a much wider beach during the previous century. Much of the former beach was lost during construction of a railroad embankment around 1901. Following the 1946 tsunami, construction of a wider highway fill along the railroad right-of-way further decreased the width of the beach. The offshore area is primarily lava rock with a thin veneer of mud and silt. Large blocks of concrete rubble which lie offshore were deposited by the 1960 tsunami.

The shoreline between Hilo Bay and Cape Kumukahi is very irregular primarily because much of it consists of recent lava flows which have been little altered by wave action. However, the very low sea cliffs at Lelewi Point are evidence of some coastal erosion along this reach which contains only three short reaches of sandy beach.

Shoreline problems along the northeast coast have resulted primarily from the devastating action of tsunamis rather than from long-term erosion processes. The tsunamis of April 1946 and May 1960 were particularly disastrous. The April 1946 tsunami caused approximately \$28 million dollars damage to Hilo and the immediate vicinity, and the loss of 96

lives (figures 31 and 32). The May 1960 tsunami reduced the Hilo bayfront area to rubble, and caused approximately \$24 million dollars of damage to the Hilo area and the loss of 61 lives.

Southeast Shore (plate 37). Except for a few scattered rural communities, the shoreline between Cape Kumukahi and South Point is undeveloped. Most of the undeveloped reaches are marginally or totally inaccessible by land.

The shoreline between Cape Kumukahi and Kalapana consists of low sea cliffs and the constructional surface of recent lava flows. It is irregular from clinker masses, collapsed lava tubes, and other structures of lava flows. The rough outline of this coast is being gradually smoothed out by wave action, and would eventually be transformed to low sea cliffs.



Fig. 32 Destruction along a section of Hilo Bay resulting from the tsunami of April 1, 1946



Fig. 31 Effects of the tsunami of April 1, 1946 on the waterfront business area of Hilo, Hawaii

The slightly arcuate, 1,000-foot-long, and 75-foot-wide black sand beach at Kaimu (figure 33) is the most publicized of all the small black sand beaches which have been created by the explosion and chilling of lava flows entering the ocean. The sand at this beach is composed almost entirely of volcanic glass and lava fragments which give the sand its famed black color. The sand is moderately well sorted and very coarse in size, and includes some gravel-sized components. Critical erosion has reduced the beach to a 300-foot-long, 30-to 40-foot-wide strip at the southwestern end. Lava rock and boulders are exposed at the southwestern end (figure 34) and coconut trees lining the backshore are being undermined (figure 35). Since 1900, the beach has eroded an average of about 275 feet along its entire length. The average annual rate of erosion is estimated to be 4 feet per year. The severity of the erosion problem led to a request from the County of Hawaii for Federal assistance in an erosion control project for this beach. Engineering plans to control the erosion problem are currently being completed by the Corps of Engineers.

The 900-foot-long, 100-foot-wide black sand beach fronting a public park at Kalapana is similar in composition to that at Kaimu Beach. Much of this beach has been reduced to cobbles, a result of erosion and sand blown inland into dunes.

The reach extending from Kalapana to South Point is primarily sea cliffs formed by erosion of recent lava flows. This reach contains only three sandy beaches, two of which front on undeveloped, marginally accessible land near South Point. The third beach fronts the village of Punaluu, and is 900 feet long and 70 feet wide. This slightly arcuate pocket beach

is composed almost entirely of black volcanic glass which ranges in grain size from medium to very coarse.

Southwest Shore (plate 38). The coast from South Point to Keawekaheka Point north of Kealahou Bay is inaccessible by land except for a few very rough jeep trails. A few small pocket beaches lie along the 8-mile reach between Kauna Point and Okoe Bay. The shoreline north of Okoe Bay is irregular and consists of sea cliffs and faults. The cliffs are high where the faults are both close to and parallel to the shoreline. Pali Kaholo between Hookena and Milolii follows a fault and is relatively high, about 500 feet at its maximum but less than 250 feet along most of its length. However, the coast north of Hookena and south of Milolii is flatter because of the absence of faults. Milolii Village is noteworthy as a Hawaiian village which is relatively isolated from other communities, and is therefore one of the few communities with a nearly self-sufficient economy.

Several littoral cones, formed by black basalt glass from the explosion and chilling of lava flows entering the ocean, are present along the shoreline. A few small black sand beaches adjacent to the cones were formed by erosion of the cones.

The 600-foot-long, 100-foot-wide arcuate pocket beach at Hookena is one of the few sandy beaches within this reach. The beach is bound at each end by basaltic rock and along the backshore by a 100-foot-high fault escarpment of lava basalt (figure 36). Nearly equal proportions of volcanic and calcareous grains form the medium-sized, moderately sorted sand which extends inland beneath a coconut grove to the talus at the base of the fault escarpment. The sand extends about 100 feet from shore.



Fig. 33 Aerial view of Kaimu Beach on the island of Hawaii

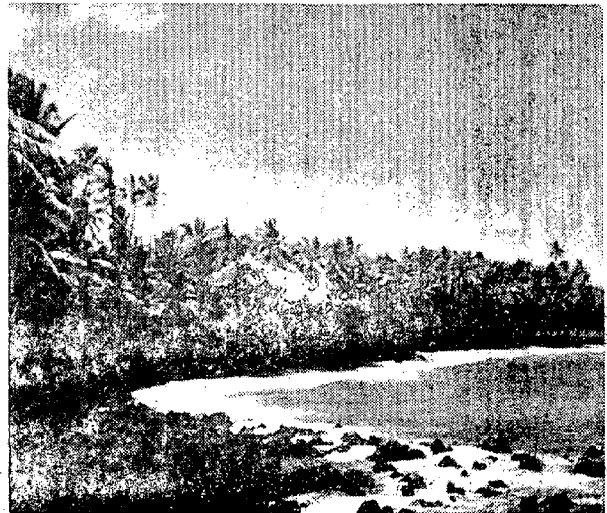


Fig. 34 Exposed lava rock and boulders at Kaimu Beach

A 600-foot-long, 60-foot-wide beach lies at the southern end of Kealakekua Bay. The sand is poorly sorted, coarse in grain size, and consists of a mixture of grains which are slightly more calcareous than volcanic. At sea level, patches of sand alternate with lava and with boulders and cobbles composed of lava and coral. Similar rocks lie awash as far as 300 feet from shore, after which a coral reef gently slopes to a depth of 10 feet at a distance of 800 feet from the beach. Beyond this point, the reef drops off quite rapidly.

A sandy pocket beach once existed at Napoopoo along the center section of the Kealakekua Bay shoreline. However, this beach has been lost to erosion.

Northwest Shore (plate 38). Much of the reach between Kealakekua Bay and Upolu Point is undeveloped. However, the rapidly expanding resort developments along this "Gold Coast" (figure 37) are expected to alter the situation. Although much of

the highly irregular shoreline consist of low sea cliffs, this coast has more sandy beaches than any other coast of the island. The beaches are usually pocket beaches in slight bays formed between lava projections, and have high calcareous content.

A 300-foot-long, 50-foot-wide beach south of Kailua Bay is popularly known as Disappearing or Magic Sands Beach because of its marked change between the winter and summer months. During the winter erosion completely denudes the beach, exposing lava and boulders at the shoreline (figure 38). However, during the summer, a 2-foot-thick layer of sand covers the rock at the foreshore (figure 39). The sand is a well-sorted, medium-grained mixture of predominantly calcareous limestone with a small percentage of volcanic detritus. A coconut grove occupies the backshore which usually retains its sand throughout the year. A large sand pocket lying offshore contains up to six feet of sand during the summer months.



Fig. 35 Undermined coconut tree at Kaimu Beach



Fig. 36 Hookena Beach, Hawaii

This pocket is believed to serve as a repository for the eroded winter sand.

The shoreline along Kailua Bay has been altered by construction of a commercial harbor at the north end of the bay. The harbor consists of an approximately 500-foot-square turning basin, a barge pier which extends about 350 feet into the bay, and a launching ramp.

Between Kailua Bay and Honokohau, the shoreline consists of low sea cliffs at the terminus of recent lava flows. The coastline at Honokohau about 4 nautical miles north of Kailua Bay has been altered by construction of a small boat harbor. The Federal portion of the harbor, completed in March 1970, consists of a 14.5-acre landlocked harbor basin made accessible to the sea by a 965-foot-long, 120-and 160-foot-wide entrance channel. Construction of the pier and shoreside facilities to accommodate the design capacity of 450 boats will be accomplished by the State of Hawaii.

The shoreline between Honokohau and Kawaihae was undeveloped and physically inaccessible until about 1964. This stretch of about 30 miles contains about 16 pocket beaches which ranges in size from about 300 feet in length to the 2,200-foot-long, 160-foot-wide beach at Hapuna Bay (figure 40). Hence, this sector contains most of the relatively rare recreational beaches on the island of Hawaii. At Kaupulehu is the Kona Village Resort, a hotel which has a private airstrip and an all-weather paved road over rough lava flows to the highway. Three miles northeast of this hotel is Kiholo Bay which has a small pocket beach. Between Kiholo Bay and Hapuna

Beach Park are two of the smaller pocket beaches at Anuehoomalu and Lahuipuaa.

The Boise Cascade Corporation is currently developing the area in the vicinity of Hapuna Beach and has completed a new access road into the area. Between Hapuna Beach and Spencer Park, the elaborate Maunakea Beach Hotel has been built with a small but beautiful coral beach about 300 feet long.

The 400-foot-long, 160-foot-wide beach at Spencer Park at the south end of Kawaihae Bay is the last of the sandy beaches along the northwest shore. This pocket beach is bound by lava points at each end. The sand is predominantly well sorted, medium-sized grains of calcareous limestone. It is about 3.5 feet thick at mean lower low water. Offshore, the sand is about 2 feet thick for a distance of 300 feet where a shallow reef covered with algae and marked by numerous sand pockets is exposed.

Construction of Kawaihae Harbor in 1959 substantially altered the natural shoreline along the north end of Kawaihae Bay. The harbor was created by dredging part of an extensive coral reef which extends about 4,000 feet seaward and more than a mile south along the shoreline. The second largest harbor on the island, Kawaihae Harbor is primarily a commercial navigation facility. However, the State of Hawaii has constructed two recreational boat harbors, one at each end of the shoreside facilities for the commercial navigation harbor. The existing Kawaihae Harbor consists of a 400-to 520-foot wide, 2,900-foot-long, 40-foot-deep entrance channel, a 1,250-foot-square, 35-foot-deep harbor basin, and a 2,650-foot-long protective rubblemound breakwater.

In response to a request from the State of Hawaii, the Corps of Engineers is developing plans for construction of a recreational boat harbor immediately south of the existing revetted fill area for the commercial navigation harbor. As part of a research and development program, the Corps has completed construction of the entrance channel and turning basin for the harbor, using an explosive cratering technique. An 850-foot breakwater has been constructed to protect the turning basin, and a launching ramp is currently being constructed.

The remaining reach from Kawaihae to Upolu Point is a marginally accessible shoreline of moderately high sea cliffs.

Northeast Shore (plate 38). The northeast shore from Upolu Point to Waipio Valley is characterized by sea cliffs ranging from 100 to 1,400 feet in height. Developments along this shore are primarily rural communities which are economically tied to the sugar plantations which line this coast.

The sea cliffs between Upolu Point and Pololu Valley are of moderate height, while those between Pololu and Waipio Valleys rise to about 1,400 feet. The sea cliffs southeast of Waipio Valley are much

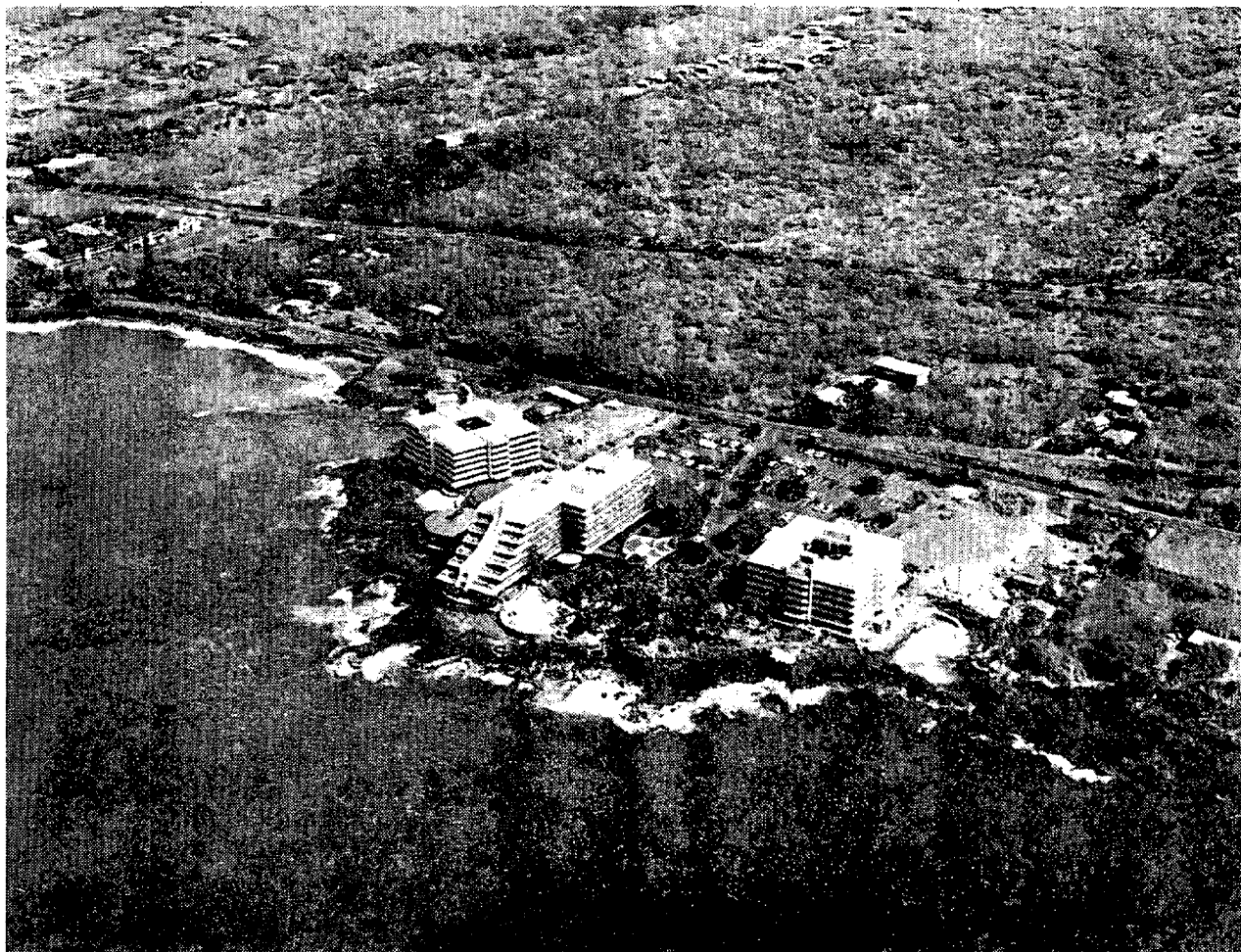


Fig. 37 Resort developments along the Kona Coast, Hawaii

lower, rising to only 200 feet. Deep valleys such as Pololu and Waipio Valleys exist between the steeper sea cliffs. These valleys have sand beaches at their mouths, with sand dunes blown inland which are as high as 50 feet.

The 1,200-foot-long, 125-foot-wide fairly straight beach at the mouth of Pololu Valley is composed of well-sorted, medium-sized detrital grains of lava fragments (figure 41). The sand is more than 3 feet deep at sea level. A shallow, sandy bottom extends at least 250 feet offshore where the bottom drops off at a fairly steep slope.

The beach at the mouth of Waipio Valley is about 4,000 feet long and 200 feet wide (figure 42). Sand dunes lie behind this slightly arcuate beach which is predominantly composed of well-sorted, medium-sized grains of volcanic detritus, with only a small

percentage of calcareous components. The sand shifts to the southeast end of the beach during late fall and to the northwest end during early spring. Thus, a boulder beach exists at the southeast end during the spring, summer, and early fall, and at the northwest end during the winter. Nearshore currents are to the northwest during spring, and to the southeast during late fall.

SUMMARY

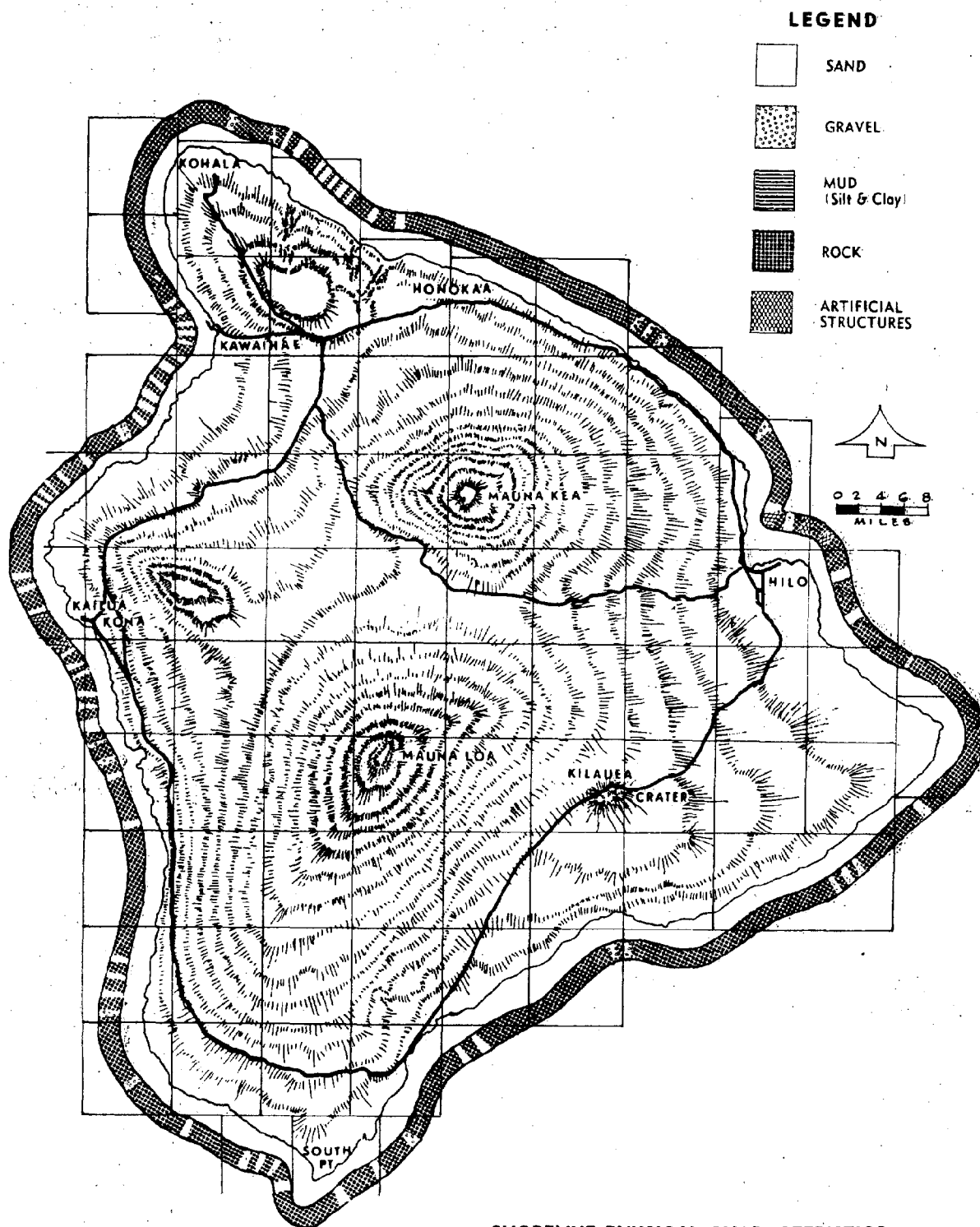
Approximately 2.1 miles of the 305.5 miles of shoreline around the island of Hawaii have been critically eroded; about 3.2 miles have a history of erosion but the problem is not critical at this time; and the remaining 300.2 miles have a history of stability or accretion.



Fig. 38 *Disappearing Sands Beach, Hawaii, during the winter (West Hawaii Today Photo)*



Fig. 39 *Disappearing Sands Beach during the summer (West Hawaii Today Photo)*



**SHORELINE PHYSICAL CHARACTERISTICS
ISLAND OF HAWAII**

PLATE 34



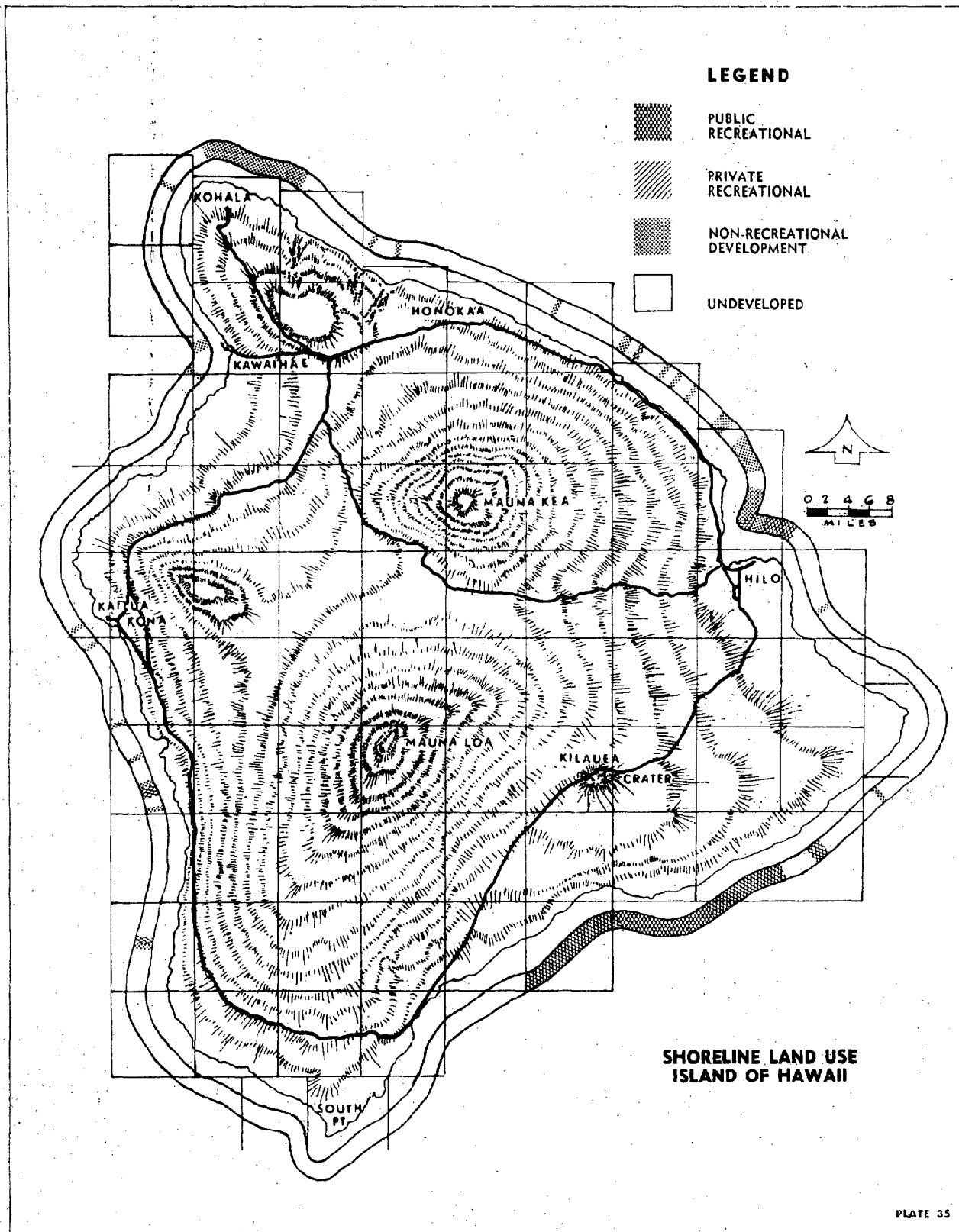
Fig. 40 *Hapuna Beach, Hawaii*



Fig. 41 *Pololu Beach, Hawaii*



Fig. 42 *Waipio Beach, Hawaii*



LAND OWNERSHIP — 1962

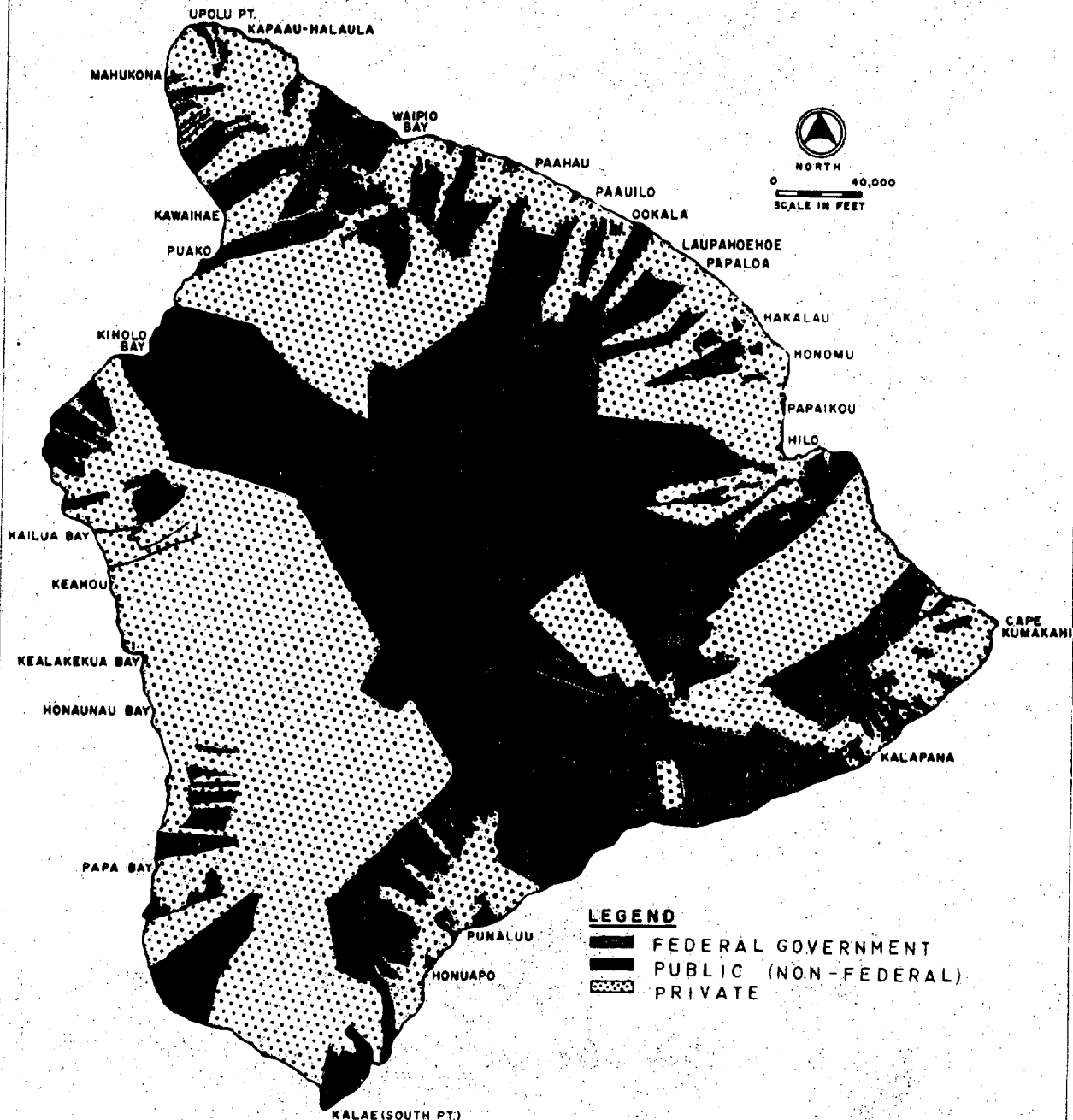
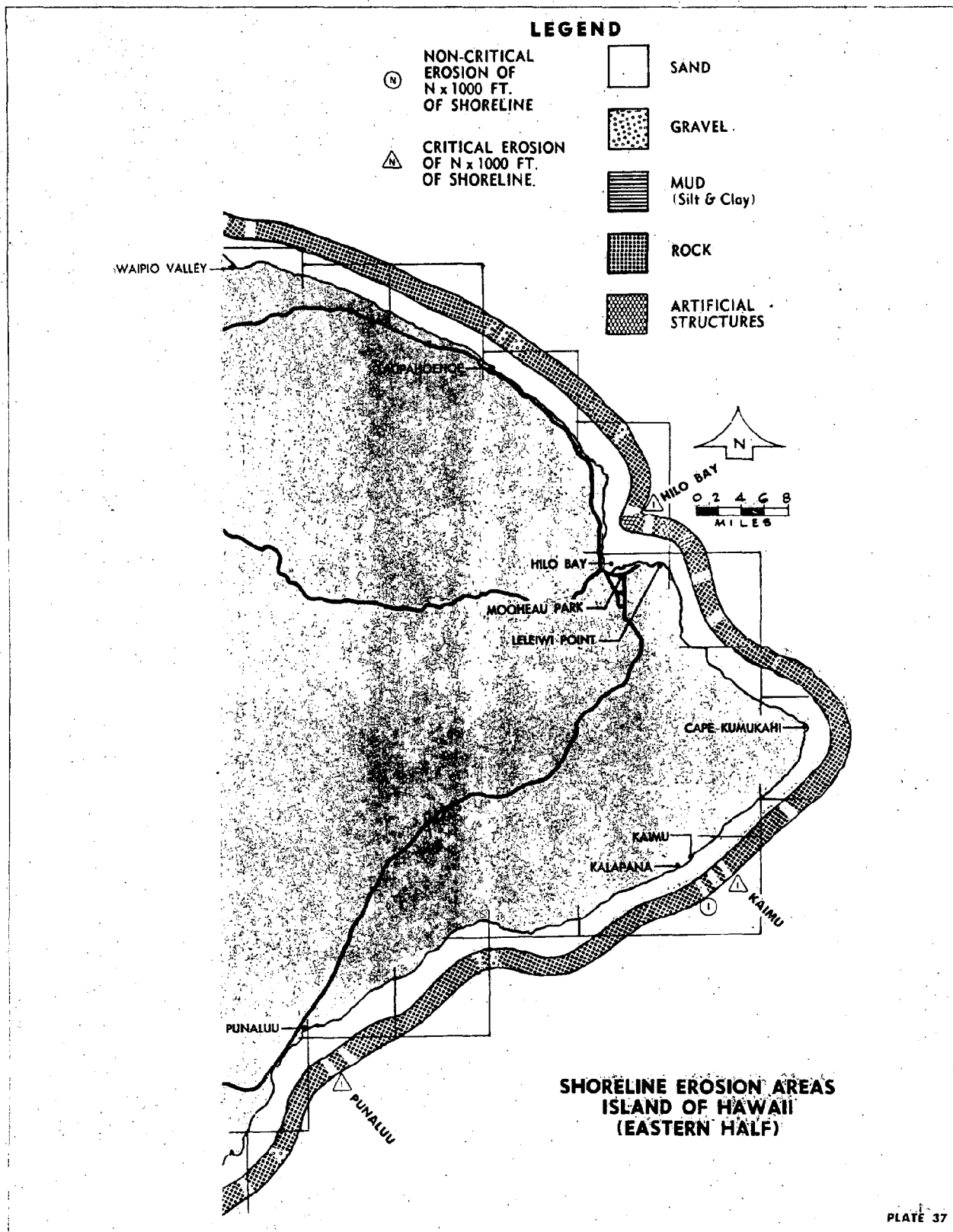
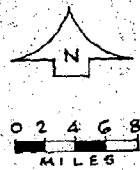









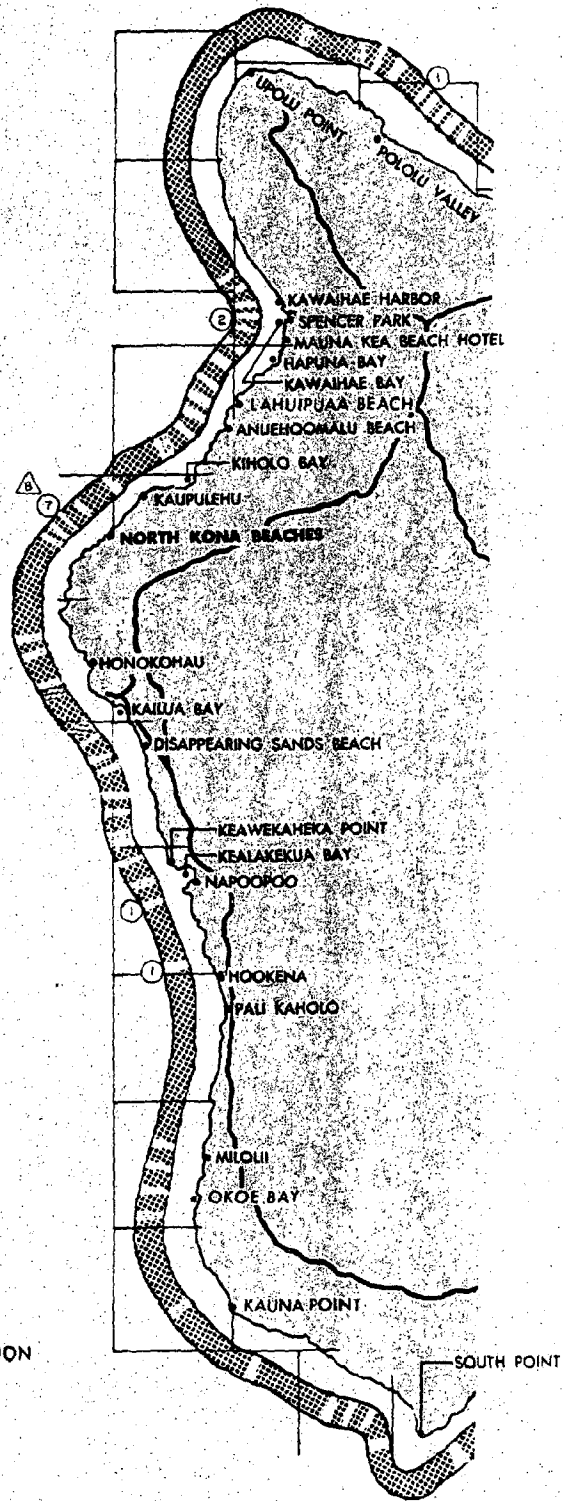
PLATE 36





LEGEND

-  SAND
-  GRAVEL
-  MUD (Silt & Clay)
-  ROCK
-  ARTIFICIAL STRUCTURES
-  NON-CRITICAL EROSION OF N x 1000 FT. OF SHORELINE
-  CRITICAL EROSION OF N x 1000 FT. OF SHORELINE



**SHORELINE EROSION AREAS
ISLAND OF HAWAII
(WESTERN HALF)**

IMPROVEMENT METHODS

SUITABLE REMEDIAL MEASURES

As defined earlier in this report, areas undergoing erosion are considered to be critical if the rate of erosion, when considered in conjunction with present and projected (15 years) economic, industrial, recreational, agricultural, navigational, demographic, ecological and other relevant factors, indicates that action to halt erosion may be justified. **Table 26** shows the 54 areas with a total shoreline length of more than 31 miles which are considered to be critically eroding. Some of these areas require immediate remedial action in the form of structural improvements. The type of structural measure considered suitable to the particular problem area is included in the table. However, it is only a suggested method and is based on present knowledge of the problem, projected shoreline use, and current engineering technology and experience in shore protection works. Additional detailed investigation of the problem and its impact on the environment, and evaluation of the engineering and economic feasibility of alternative solutions are required before any solution can be implemented.

In addition to the areas requiring immediate remedial action, **table 26** includes areas where remedial action would be required within 5 to 15 years. The type of improvement required would depend on whether effective coastal zone management is implemented to minimize the adverse effect of erosion on shoreline developments. Implementation of such measures today would reduce the extent and cost of structural improvements which would be required at a later date. Because it is difficult to predict the type of improvement which would be required, several suitable types of remedial measures are suggested for these areas.

The estimated cost of the remedial work suggested in the table is based on 1971 price levels in Hawaii, and totals about \$32 million for the 54 areas.

In order to preserve the natural beauty of the shoreline, protective works should be aesthetically pleasing. This can be accomplished in part by a low-profile concept for groins and breakwaters whereby these structures would visibly extend only a foot or so above the sand and water as depicted in **plate 39**. In some areas landscaped groins and islands should be considered. An example of this type of treatment is shown in the shoreline photograph of the Kahala Hilton Hotel on Oahu (**figure 10**).

FEDERAL PROGRAMS

Under the direction of the Congress of the United States, the Corps of Engineers has constructed shore protection and navigation projects for many years. The Corps' first project in Hawaii was the 1909 authorization to modify Honolulu Harbor. Currently, the Corps of Engineers office in Hawaii is undertaking the projects and studies listed in **tables 27** and **28**, respectively. All of the projects and studies were either directly or indirectly authorized by the Congress and are the result of a request for Federal assistance from State of Hawaii or county government agencies. In addition to the studies currently in progress, **table 28** lists the navigation and beach erosion studies which the Congress has directed the Corps of Engineers to conduct with the objective of determining whether Federal assistance can be provided in developing a solution to the problem under investigation.

SHORE PROTECTION TECHNOLOGY

The U.S. Army Coastal Engineering Research Center (formerly the Beach Erosion Board) has been studying shore erosion and protection problems since 1930. The Center is deeply involved in investigations of shore processes, storm frequencies, and storm-tide elevations. Research into remedial measures is accomplished at the Center by its engineers and scientists; in addition, many significant programs are carried out by universities and private research organizations under contracts with the Center. Much of the field work essential to those research efforts is accomplished by staff members of the various Corps of Engineers Districts. The results of this research are published and widely disseminated in the United States, and are also supplied on an exchange basis to foreign institutions and agencies. As a result of this exchange, the Coastal Engineering Research Center is well informed of world-wide progress. One of a series of publications prepared by the Center is Technical Report No. 4, "Shore Protection, Planning and Design" which provides information and methods currently used in the solution of shore protection problems. Technical Report No. 4, commonly known as T.R. 4 among the Coastal Engineers of the world, provides the most comprehensive presentation of shore protection technology available in a single publication. (Complimentary to and less technical than T.R. 4 is the Center's Shoreline Protection Guidelines Report which was published in 1971 as a part of the National Shoreline Study. The purpose of this report is to enable State and local authorities to plan effective

Table 26
Suitable Beach Erosion Control Measures

Beach	Critical Erosion in 1,000 Feet	Type of Major Damage	Suitable Remedial Measures	Estimated Costs per Affected 1,000 Feet			
				Initial \$	Annual Nourishment \$	Total First Cost \$	
							Total Annual Nourishment \$
ISLAND OF OAHU							
Waimanalo Beach Park.....	2	Loss of Recreational Beach	See Note	300,000	2,000	600,000	4,000
Sandy Beach Park**.....	2	Loss of Recreational Beach	See Note	300,000	2,000	600,000	4,000
Hanauma Bay Beach Park**.....	2	Loss of Recreational Beach	Widen Beach 75 feet and Periodic Nourishment	270,000	2,000	540,000	4,000
Maunaloa Beach Park**.....	1	Loss of Recreational Beach	Widen Beach 25 feet, low profile groins, and periodic nourishment	300,000	2,000	300,000	2,000
Kahala Hilltop.....	1	Loss of Recreational Beach	Periodic Nourishment	2,000	2,000	2,000	2,000
Waialae-Kahala.....	3	Minor property damage and loss of beach	Widen Beach 25 feet, low profile groins, and periodic nourishment	150,000	2,000	450,000	6,000
Waikiki*.....	9	Loss of Recreational Beach	Widen Beach 100 Feet, groins, and periodic nourishment	400,000	2,000	3,600,000	18,000
Ala Moana Beach Park.....	2	Loss of Recreational Beach	See Note	300,000	2,000	600,000	4,000
Kechi Lagoon Area**.....	2	Loss of Recreational Beach	See Note	300,000	2,000	600,000	4,000
Ewa Beach Residential**.....	4	Loss of Beach	See Note	100,000	2,000	400,000	8,000
Mali Beach Park**.....	2	Loss of Recreational Beach	Wave Absorber along existing jetty	100,000	2,000	200,000	4,000
Pokai Military.....	2	Loss of Recreational Beach	Widen beach 100 feet and offshore breakwater	400,000	0	800,000	0
Makaha Beach Park**.....	2	Loss of Recreational Beach	Periodic Beach Nourishment	20,000	4,000	40,000	8,000
Mokulea Residential**.....	10	Major Property Loss	See Note	150,000	0	1,500,000	0
Haleiwa Residential.....	1	Major Property Loss	See Note	150,000	0	150,000	0
Kaunaloa Residential.....	2	Major Property Loss	See Note	150,000	0	300,000	0
Sunset Residential.....	6	Major Property Loss	See Note	200,000	0	1,200,000	0
Waialeale Residential.....	1	Major Property Loss	See Note	150,000	0	150,000	0
Kawela Bay Residential.....	2	Major Property Loss	See Note	150,000	0	300,000	0
Laniloa Pt. to Hauula Residential**.....	1	Minor property damage and loss of beach	Low Profile Groins and Breakwaters	100,000	0	100,000	0
Hauula Beach Park**.....	2	Loss of Recreational Beach	Widen Beach 75 feet, low profile groins and breakwaters, and periodic nourishment	330,000	2,000	660,000	4,000
Hauula to Punaluu**.....	2	Minor Property damage and loss of beach	See Note	400,000	0	200,000	0
Residential Beaches**.....	1	Loss of Recreational Beach	Widen Beach 75 feet, low profile breakwaters, and periodic nourishment	330,000	2,000	330,000	2,000
Punaluu to Kahana Bay Residential Beaches.....	2	Minor Property Damage and Loss of Beach	See Note	400,000	0	200,000	0
Swanoy Beach Park**.....	1	Loss of Recreational Beach	Widen Beach 75 feet, low profile breakwaters, and periodic nourishment	330,000	2,000	330,000	2,000
Swanoy to Kaawaa Residential Beaches**.....	1	Minor Property Damage and Loss of Beach	See Note	400,000	0	200,000	0
Kaawaa Beach Park**.....	2	Loss of Recreational Beach	Widen Beach 75 feet, low profile breakwaters, and periodic nourishment	330,000	2,000	660,000	4,000
Roadside Beach**.....	3	Loss of Recreational Beach	See Note	300,000	2,000	900,000	6,000
Mokapu Marine Corps.....	1	Loss of Beach	Widen Beach 75 feet, low profile breakwaters, and periodic nourishment	150,000	0	150,000	0
Kailua Residential.....	3	Loss of Beach	See Note	100,000	0	300,000	0
Lanikai Residential.....	3	Loss of Beach	Low Profile Groins and Breakwaters	100,000	0	100,000	0
Belkows Military.....	2	Loss of Beach	Widen Beach 75 feet, low profile breakwaters, and periodic nourishment	150,000	0	300,000	0

Table 25 continued
Suitable Beach Erosion Control Measures

Beach	Critical Erosion in 1,000 Feet	Type of Major Damage	Suitable Remedial Measures	Estimated Costs per Affected 1,000 Feet			
				Initial \$	Annual Nourishment \$	Total First Cost \$	
							Annual Nourishment \$
ISLAND OF KAUAI							
Hanalei*	3	Loss of protective beach	Shore reversion	110,000	0	120,000	0
Waimea West*	3	Loss of protective beach	Low profile groins	100,000	0	300,000	0
Kekaha	8	Loss of protective beach	See Note	200,000	0	1,400,000	0
Barking Sands	8	Loss of protective beach	See Note	200,000	0	1,400,000	0
Kapaa	1	Loss of recreational beach	Low profile groins and periodic nourishment	200,000	2,000	800,000	8,000
Waialeale**	1	Loss of recreational beach	Low profile groins and periodic nourishment	200,000	2,000	200,000	2,000
ISLAND OF MOLOKAI							
Pohakuloa to Pukou	8	Loss of beach	See Note	100,000	0	800,000	0
Holena	5	Loss of beach	See Note	100,000	0	500,000	0
ISLAND OF MAUI							
Waiehu Area	3	Loss of protective beach	See Note	150,000	0	150,000	0
Kahului Harbor	1	Loss of protective beach	Shore Reversion	150,000	0	150,000	0
Sprecklesville	3	Loss of protective beach	Permanent discontinuance of Sand Mining	0	0	0	0
Puu Ohihi to Kamaole Park	1	Loss of Recreational Beach	See Note	100,000	2,000	400,000	8,000
Kihati	4	Loss of protective beach	Low profile groins and breakwaters	100,000	0	100,000	0
Olowalu	3	Loss of Recreational Beach	See Note	100,000	2,000	300,000	6,000
Lahaina Residential	2	Loss of protective beach	See Note	100,000	0	200,000	0
Hanalei Point	6	Loss of Recreational Beach	Low profile groins and breakwaters, and periodic nourishment	100,000	2,000	600,000	12,000
Kaanapali	1	Loss of Recreational Beach	See Note	100,000	2,000	400,000	8,000
ISLAND OF LANAI							
Poiihina	1	Loss of Recreational Beaches	See Note	150,000	0	600,000	0
ISLAND OF HAWAII							
Hilo Bay	1	Loss of Beach	Low Profile Groins	100,000	0	100,000	0
Kaunua Black Sands**	1	Loss of Recreational Beach	Widen Beach 50 feet and breakwater	800,000	1,000	800,000	1,000
Punaluu Beach Park	1	Loss of Recreational Beach	See Note	800,000	1,000	800,000	1,000
North Kona Area**	8	Loss of Recreational Beaches	See Note	300,000	2,000	2,100,000	16,000

*Authorized Federal Project

**Authorized Federal Study

Note: A suitable remedial measure would include one or more of the following items—groins, breakwaters, artificial islands, shore reversion, erosion resistant plantings, beach replenishment, and periodic nourishment. Cost estimate is based on past cost estimates for beaches having similar characteristics of structure, wave exposure, and shore use.

Table 27
Authorized Federal Projects for Hawaii
As of April 1971

Types of Project	Status	Location
Beach Erosion	Completed in 1957	Waikiki Beach, Oahu
	Constructed in 1965	Haleiwa Beach Park, Oahu
	Under Construction	Kihei Beach, Maui
	Pre-Construction Planning	Kuhio Beach Sector, Waikiki Beach (being accomplished by the State of Hawaii, subject to Corps approval)
		Fort DeRussy-Royal Hawaiian Hotel Sector, Waikiki Beach, Oahu
	Design and Construction to be accomplished by the State of Hawaii with 50% Federal reimbursement	Hanapepe Beach, Kauai
	Pre-construction planning to be accomplished upon receipt of project funds	Waimea Beach, Kauai
		Duke Kahanamoku Sector, Waikiki Beach, Oahu
		Kuhio Beach-Elks Club Sector, Waikiki Beach, Oahu
Navigation	Completed	Haleiwa Recreational Harbor, Oahu
		Hilo Harbor, Hawaii
		Honokohau Recreational Harbor, Hawaii
		Honolulu Harbor, Oahu
		Kahului Harbor, Maui
		Kalaupapa Harbor, Molokai
		Kaunakakai Harbor, Molokai
		Manele Recreational Harbor, Lanai
		Nawiliwili Harbor, Kauai
		Port Allen Harbor, Kauai
	Advertised for construction	Kawaihae Commercial Navigation Harbor Modification, Hawaii
	Pre-construction planning	Kawaihae Recreational Boat Harbor, Hawaii
		Nawiliwili Recreational Boat Harbor, Kauai
		Lahaina Recreational Boat Harbor, Maui
		Honolulu Harbor Modification, Oahu
		Barbers Point Commercial Navigation Harbor, Oahu
		Maunaloa Recreational Boat Harbor, Oahu
		Kewalo Harbor, Oahu
	Preconstruction planning to be accomplished upon receipt of project funds	Maalaea Recreational Boat Harbor, Maui
		Reeds Bay Recreational Boat Harbor, Hawaii
		Waianae Recreational Boat Harbor, Oahu
		Ala Wai Boat Harbor, Oahu
		Hana Recreational Boat and Barge Harbor, Maui
		Hanalei Recreational Boat Harbor, Kauai

Types of Project**Status****Location**

Heeia Kea Recreational Boat Harbor, Oahu
 Kailua Recreational Boat Harbor, Oahu
 Kaunakakai Recreational Boat Harbor, Molokai
 Kaunakakai Commercial Navigation Harbor, Molokai
 Kikiaola Recreational Boat Harbor, Kauai
 Nawiliwili Commercial Navigation Harbor, Oahu

Table 28
Authorized Federal Studies for Hawaii
As of April 1971

Type of Study**Status****Location****Beach Erosion**

Under investigation

Kaimu Beach, Hawaii
 Kaaawa Beach, Oahu
 Hanauma Beach, Oahu
 Hauula Beach, Oahu
 Punaluu Beach, Oahu
 Punaluu Beach, Hawaii
 Swanzey Beach, Oahu
 Maili Beach, Oahu
 Wailua Beach, Kauai
 Kona Area, West Hawaii
 Maunalua Bay, Oahu
 Mokuleia Area, Oahu
 Keehi Lagoon Area, Oahu
 Sandy Beach Park, Oahu
 Ewa Beach Park, Oahu
 Maile-Waianae Coast, Oahu
 Maalaea Medium-Draft Harbor, Maui
 Kahului Harbor, Maui (Emergency Repair of Breakwater)
 Haleiwa Recreational Boat Harbor, Oahu (Harbor Modification)
 Hilo Harbor, Hawaii (Harbor Modification)
 Kahaluu Harbor, Oahu

Navigation

Under investigation

To be investigated upon receipt of study funds

shore protection works. The report describes typical control structures, non-structural alternatives, examples of present shore protection facilities, and discusses their strengths and shortcomings, and presents criteria for planning, designing, using and maintaining structural protection.)

Present knowledge of shoreline processes in Hawaii reflects past studies that have developed information on coastal currents, wave climate, beach profiles and materials, and the relationship of beaches to reef ecology.

COASTAL CURRENTS.

The most complete published analysis of coastal currents around the Hawaiian Islands is contained in the University of Hawaii's 1964 HIG-64-1 report. This work discusses coastal currents in terms of the various components which include the Pacific North Equatorial Current, the tidal current, wind-driven currents, and wave-induced currents. Drawings showing generalized current patterns around each of the major islands for both flood and ebb tide conditions are shown. More extensive investigations are desirable to develop information on current patterns for inshore areas. Research on water level buildup and current patterns caused by breaking waves and onshore winds in shallow reef areas are needed.

WAVE CLIMATE.

The most complete summary on the sources of existing wave data for the islands is contained in the Corps of Engineers 1964 publication, "Hawaiian Island Beaches."

The frequency of occurrence and meteorological factors of the four principal sources of Hawaiian waves—northeast tradewind waves, northern swell from North Pacific winter storms, local storms, and southern swell—are discussed in the University of Hawaii's HIG-64-2 report.

Wave records obtained at Kahului Harbor, Maui, during 1966 to 1968 have been analyzed by the Coastal Engineering Research Center. The University of Hawaii's Look Laboratory of Oceanographic Engineering is currently obtaining continuous wave records off the entrance to Kewalo Harbor, Oahu, in conjunction with a research study of surfing conditions. The University's Hawaii Institute of Geophysics is recording wave data in Kaneohe Bay, Oahu, which will be used in their research efforts to correlate wave action with coral reef growth and damage.

In 1971, the Tsunami Research Center installed two wave gages on the north shore of Oahu off the Mokuia area in a joint effort between the University of Hawaii and the National Oceanic and Atmospheric Administration. One gage is in about 1,500 feet of water and one in about 100 feet of water. The program is a continuous program concerned with both tsunami

warning and high surf warning. The Tsunami Research Center is also planning to install six wave gages in about 30 feet of water off the north shore of Oahu for a short term research study entitled "Study of Transformation of Ordinary Wind Wave Energy into Surf Beat and Edge Waves" which is being funded by the National Science Foundation.

For individual shoreline projects, the Corps of Engineers supplements existing wave information with wave hindcasts of significant ocean storms pertinent to the study area.

There is a need for additional deep water wave research to provide a comprehensive statistical report on the duration, height, period, and direction of waves approaching the islands.

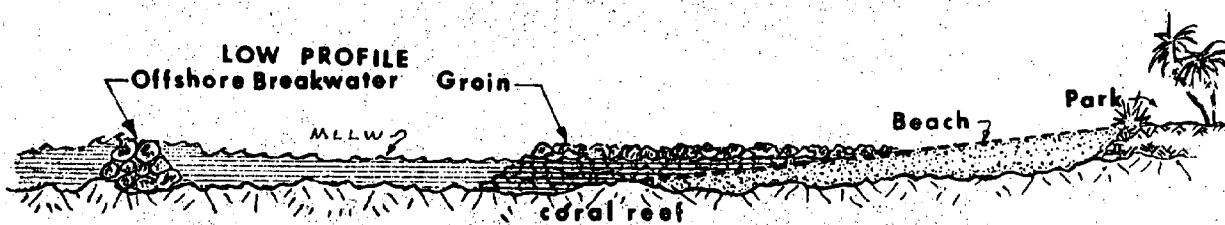
BEACH PROFILES AND MATERIALS.

The most complete compilation on beach profiles and materials is contained in the University of Hawaii's HIG-64-2 report, "Hawaiian Beach Systems." This report contains descriptions of 112 beaches, shows 150 beach profiles obtained during 1962 and 1963, and has grain-size parameters on about 2,400 sand samples.

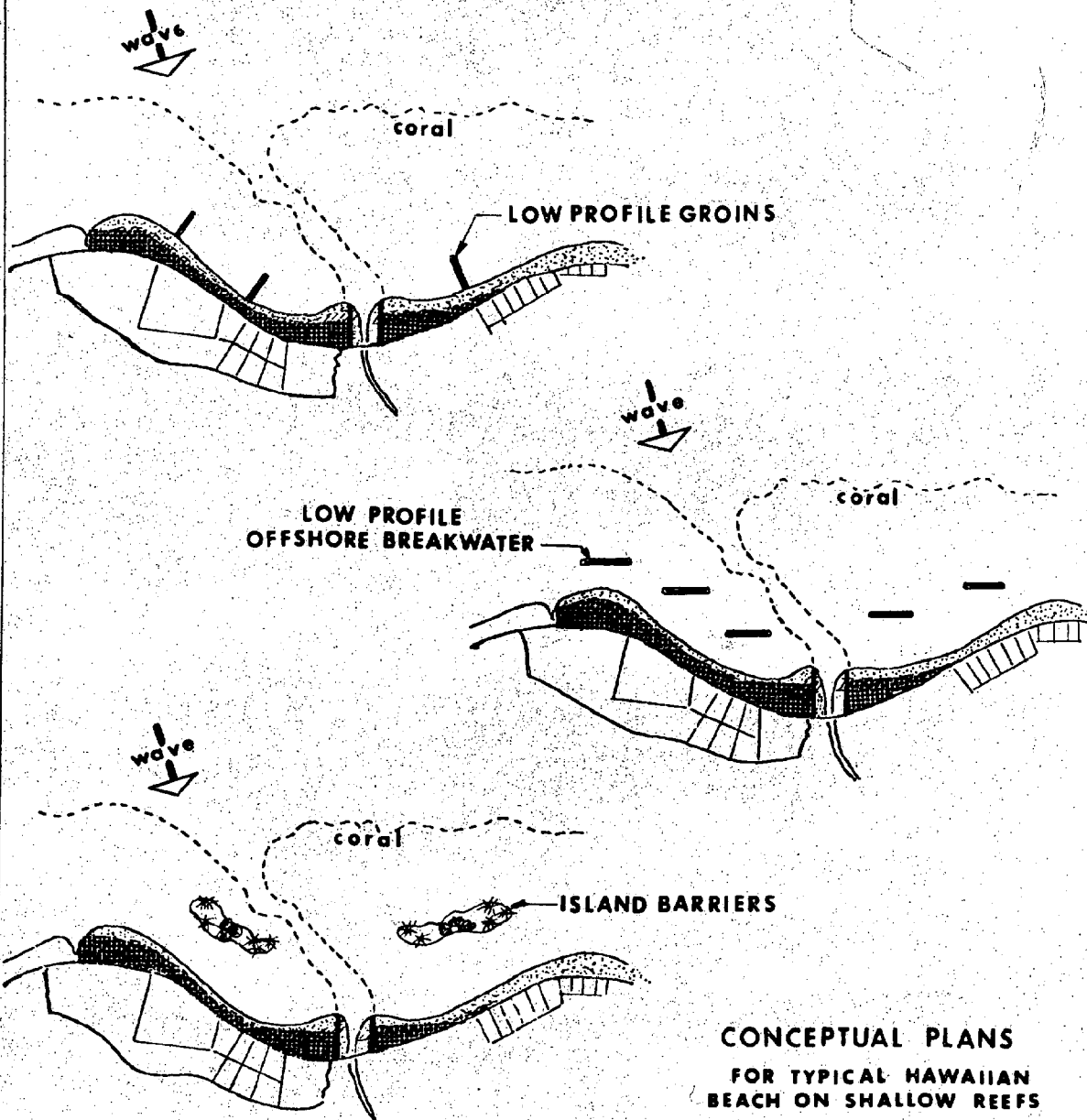
The Coastal Engineering Research Center funded studies which are being conducted by the Corps of Engineers Pacific Ocean Division on eight island beaches. An analysis on seasonal beach profiles and sand samples obtained over a three year period will be correlated with existing wind and wave data in an effort to provide a better understanding of the complex shoreline processes of the Hawaiian Islands.

SAND SOURCES.

Recent (1968, 1969, 1970) funding by the National Science Foundation has enabled the University of Hawaii to initiate an inventory of offshore sand deposits throughout the islands and to investigate the feasibility of exploiting the deposits. The results of the first year of sand recovery study are published in the University's Department of Ocean Engineering's Seagrant 69-4 report. The report summarized the results of existing research of sand uses and sand sources in the islands and indicated that, at the present rate of use of beach sand by the construction industry, Hawaiian beach sand resources would be reduced by 25 percent within 10 years; that some sand is trapped in navigation channels and subsequently dredged and spoiled at sea; that beach sand from Molokai is the current primary source of sand for the construction industry; that sand exploration has been chiefly concentrated in Kaneohe Bay and Halekulani Channel on Oahu; that Halekulani Channel sand was rejected as a source for beach replenishment by the Corps and State officials because the grain size was too small and the color and odor were



TYPICAL SECTIONAL VIEW



CONCEPTUAL PLANS
FOR TYPICAL HAWAIIAN
BEACH ON SHALLOW REEFS

PLATE 39

objectionable; that large quantities of the Kaneohe Bay sand is suitable for beach replenishment but removal has been prohibited by the State because of possible environmental effects on a nearby bird refuge; that other known deposits in Kaneohe Bay are too fine-grained; that sand removal from water depths less than 50 feet is prohibited by State policy and dredge capability has been limited to water depths of less than 60 feet; and that it is not presently economically feasible for a commercial offshore sand mining operation in Hawaii. The report concluded with the following statements—"Only the results of a continued inventory program over the next few years, coupled with unpredictable advances in ocean mining technology, will form the basis for conclusions of future reports on the feasibility of recovery of sand from the ocean surrounding the Hawaiian Islands. Such reports will be forthcoming as additional information comes to light."

About 160,000 cubic yards of shoaled material are dredged, on an average annual basis, from Hawaiian harbors by Federal hopper dredges and spoiled at sea. Methods of utilizing this material should be investigated.

RELATIONSHIP OF BEACHES TO REEF ECOLOGY

Investigations dealing with the interrelationship of beaches and reef ecology have not been well publicized. Rates of growth of reef organisms were briefly discussed in the University's HIG reports numbers 41 and 64-2.

For the past three years, Sea Grant funds have been used by the University of Hawaii's Institute of Geophysics to investigate sedimentation, pollution, and other environmental factors at Kaneohe Bay, Oahu. Preliminary findings indicate that live coral is being killed by pollution and the reef in this bay is eroding faster than it is being replaced by growing coral.

Additional research is warranted to expand present knowledge on the effects of shoreline projects on reef ecology and the nearshore environment.

NATURAL DISASTERS AND SHORELINE MANAGEMENT.

It is difficult, expensive, and in some cases, impracticable or impossible to design and construct structures to protect the coast from natural disasters such as tsunamis, landslides, earthquakes, and extremely high surf. An efficient island-wide tsunami warning system has minimized the hazard to life from tsunamis, and zoning regulations are being developed that should substantially reduce property damage from future tsunamis in such historically susceptible areas as Hilo, Hawaii.

An alternate to structural remedial measures for some of the critical erosion areas along the north shores of the islands might be through restrictive zoning and building regulations similar to the management methods being developed for areas highly susceptible to tsunamis. The north shores are subjected to extremely high surf from particularly severe storm conditions. Damages are primarily caused by flooding, undermining, and direct wave attacks on beachfront properties and are most evident along well developed coasts. During the extreme high surf of December 1969, private property along Oahu's north shore sustained damages of about one million dollars. A suggested land management alternative for the Mokuleia, Kawailoa, Sunset, Waialea, and Kawela beaches along Oahu's north shore is a restrictive building code to require open type construction for the ground floor levels of beachfront properties.

As part of the National Shoreline Study, the Corps of Engineers has published a Shore Management Guidelines report. This report provides guidance to enable governmental agencies at the State and County levels to develop programs to improve the use and management of shoreline resources. Existing Federal shore protection programs and policies and existing State and local programs are discussed. Historic and anticipated shore uses are described, principles of comprehensive planning accompanied by examples are presented, multiple-use of shore and water areas, land use planning and construction are developed. The report also discusses the principles of cost sharing and describes the nature of public and private benefits.

INFORMATION CENTER

**COASTAL ZONE
INFORMATION CENTER**

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